facultad de informática
universidad politécnica de madrid

TESIS DOCTORAL

INTERPRETACIÓN GEOMÉTRICA DE REDES NEURONALES RECURRENTES DISCRETAS MEDIANTE GRAFOS COMPLETOS

APÉNDICE

(*Mathematica 2.2.*)

R GIMÉNEZ MARTÍNEZ

DIRECTORES: PEDRO GÓMEZ VILDA
EMILIO TORRANO GIMÉNEZ

MADRID, OCTUBRE 1996.

```
(*====================   Ap 1.1.   ====================
======================              ======================
======================      X       ======================

   37 octetos correspondientes a 37 trazas de voz

X ={
{1,1,1,-1,-1,-1,1,-1},{1,1,1,-1,-1,1,-1,-1},
{1,1,1,-1,-1,-1,-1,-1},{1,1,1,-1,1,-1,1,-1},
{1,1,1,-1,1,1,1,-1},{1,1,1,1,1,1,1,-1},
{1,1,1,1,-1,-1,-1,-1},{1,-1,-1,-1,1,1,-1,-1},
{1,-1,-1,-1,-1,1,-1,-1},{1,-1,-1,-1,-1,-1,-1,-1},
{1,-1,-1,-1,1,-1,-1,-1},{1,1,-1,-1,1,1,-1,-1},
{1,1,-1,-1,-1,1,-1,-1},{1,1,-1,-1,-1,-1,-1,-1},
{1,1,-1,-1,1,-1,-1,-1},{1,1,-1,1,1,1,-1,-1},
{1,1,-1,1,1,1,-1,1},{1,1,-1,1,-1,1,-1,-1},
{1,1,-1,1,-1,1,-1,1},{1,1,-1,1,-1,-1,-1,-1},
{1,1,-1,1,1,-1,-1,-1},{1,-1,-1,1,1,1,-1,-1},
{1,-1,-1,1,1,1,-1,1},{1,-1,-1,1,-1,1,-1,-1},
{1,-1,-1,1,-1,1,-1,1},{1,-1,-1,1,-1,-1,-1,-1},
{1,-1,1,1,-1,-1,-1,-1},{1,-1,1,1,1,-1,-1,-1},
{1,-1,-1,1,1,-1,-1,-1},{1,1,-1,1,-1,1,1,1},
{1,1,-1,1,-1,1,1,-1},{1,1,1,1,-1,1,1,-1},
{1,1,1,1,-1,-1,1,-1},{-1,1,-1,-1,1,1,-1,-1},
{-1,1,-1,-1,-1,1,-1,-1},{-1,1,-1,-1,-1,-1,-1,-1},
{-1,1,-1,-1,1,-1,-1,-1}};*)
(* Save["X.m",X] *)
```

```
(*====================    Ap 1.2.   ====================
======================              ======================
======================     WHop     ======================

Read["X.m"];
p = Length[X];
WHop = (1/p)(Transpose[X].X-p*IdentityMatrix[8]);
Save["WHop.m",WHop];
Close["X.m"];
Clear[p];*)
```

```
Read["WHop.m"];
WHop
Close["WHop.m"];
```

```
      5     7    11     5     3     13
-{{0, --, -(--), --, -(--), --, -(--),
      37    37   37     37    37    37

     19     5      1     5      5    3
-- -(--)}, {--, 0, --, -(--), -(--), --,
     37     37     37    37     37   37

   3     11        7    1         1
-- --, -(--)}, {-(--), --, 0, -(--),
   37    37        37   37        37

     1      9    23  5
-- -(--), -(--), --, --},
     37     37   37  37

   11    5      1          3    5   1
-{--, -(--), -(--), 0, -(--), --, --,
   37    37     37         37   37  37

   7       5      5      1      3
-- --}, {-(--), -(--), -(--), -(--), 0,
   37      37     37     37     37

   1   1   3     3   3     9    5   1
-- --, --, --}, {--, --, -(--), --, --,
   37  37  37    37  37    37   37  37

      1   7        13   3   23  1   1
-- 0, --, --}, {-(--), --, --, --, --,
      37  37       37   37  37  37  37

   1      15       19     11   5   7
-- --, 0, --}, {-(--), -(--), --, --,
   37     37       37     37   37  37

   3   7   15
-- --, --, --, 0}}
   37  37  37
```

```
(*====================   Ap 1.3.   ====================
======================              ====================
======================    OctHop    ====================

     Octetos con componentes tomando valores -1 o 1.

OctHop0:=Permutations[{-1,-1,-1,-1,-1,-1,-1,-1}]
OctHop1:=Permutations[{1,-1,-1,-1,-1,-1,-1,-1}]
OctHop2:=Permutations[{1,1,-1,-1,-1,-1,-1,-1}]
OctHop3:=Permutations[{1,1,1,-1,-1,-1,-1,-1}]
OctHop4:=Permutations[{1,1,1,1,-1,-1,-1,-1}]
OctHop5:=Permutations[{1,1,1,1,1,-1,-1,-1}]
OctHop6:=Permutations[{1,1,1,1,1,1,-1,-1}]
OctHop7:=Permutations[{1,1,1,1,1,1,1,-1}]
OctHop8:=Permutations[{1,1,1,1,1,1,1,1}]
OctHop:=Union[OctHop0,OctHop1,OctHop2,OctHop3,OctHop4,
OctHop5,OctHop6,OctHop7,OctHop8];
Save["OctHop.m",OctHop]
*)
```

```
(*====================   Ap 1.4.   ====================
=====================               =====================
=====================   HebbHop   =====================

Clear[HebbHop]
HebbHop[x_,A_,j_Integer]:=
        Block[{n,a,b,w,v},
        n = Length[x];
        Read["Cero.m"];
        a = Cero[n,0];
        b = Cero[n,0];
        v = Cero[n,0];
        w = Cero[n,0];
        a = x;
        b = x;
        v = x;
        a[[j]] = 1;
        b[[j]] = -1;
        w = A[[j]];
        If[v.w < 0,v=b,If[v.w > 0,v=a,v=x]];
        Return[v]]

Save["HebbHop.m",HebbHop]
*)

Read["WHop.m"];
Read["HebbHop.m"];
HebbHop[{1,1,1,-1,-1,-1,-1,-1},WHop,3]
Close["WHop.m"];
Close["HebbHop.m"];
{1, 1, -1, -1, -1, -1, -1, -1}
```

```
(*====================   Ap 1.5.   ====================
======================              ====================
======================   IterHop   ====================

Clear[IterHop]
IterHop[v_,A_] :=
        Block[{t,p,a,b},
                Read["HebbHop.m"];
                a=v;b=v;
                Read["
                Do[
                b = HebbHop[a,A,i];
                a = b,{i,8}];
                Return[b]]

Save["IterHop.m",IterHop]

*)

Read["WHop.m"];
Read["IterHop.m"];
IterHop[{1,1,1,-1,-1,-1,-1,-1},WHop]
Close["WHop.m"];
Close["IterHop.m"];
{1, 1, -1, -1, -1, 1, -1, -1}
```

```
(*====================   Ap 1.6.   ====================
=====================              =====================
=====================    RecHop    =====================

Clear[RecHop]
RecHop[v_,A_] :=
        Block[{t,a,b,n},
        a = v;
        n = Length[v];
        Read["Cero.m"];
        Read["IterHop.m"];
        If [a ==Cero[n,0],b=Cero[n,0],b=Cero[n,0]];
          t=1;
          While[a!=b,
           If[t==1,
             b=IterHop[a,A],
             a=b;
             b=IterHop[a,A]];
             t=t+1];
        Return[b]]

Save["RecHop.m",RecHop]

*)


Read["WHop.m"];
Read["RecHop.m"];
RecHop[{1,1,1,-1,-1,-1,-1,-1},WHop]
Close["WHop.m"];
Close["RecHop.m"];
{1, 1, -1, 1, -1, 1, -1, -1}
```

```
(*====================   Ap 1.7.   ====================
======================             ====================
======================             ====================

Read["WHop.m"];
Read["OctHop.m"];
Read["RecHop.m"];
Table[RecHop[OctHop[[i]],WHop],{i,1,256}]
Close["WHop.m"];
Close["OctHop.m"];
Close["RecHop.m"];
{{1, 1, -1, 1, -1, 1, -1, -1},

 {-1, -1, 1, -1, 1, -1, 1, 1}}

(*====================   Ap 1.8.   ====================
======================             ====================
======================             ====================

Read["WHop.m"];
Read["OctHop.m"];
A=Table[-(1/2)*(OctHop[[i]].WHop.OctHop[[i]]),{i,1,256}];
x={1,1,-1,1,-1,1,-1,-1};
Ex = -(1/2)*(x.WHop.x)
Do[If[A[[i]]<=Ex,Print[OctHop[[i]]],],{i,1,256}]
Close["WHop.m"];
Close["OctHop.m"];
  120
—(---)
  37
{-1, -1, 1, -1, 1, -1, 1, 1}
{1, 1, -1, 1, -1, 1, -1, -1}
```

```
(*====================   Ap 3.1.   ====================
=======================             =======================
=======================     L       =======================

   37 octetos correspondientes a 37 trazas de voz

L ={
{1,1,1,0,0,0,1,0},{1,1,1,0,0,1,0,0},{1,1,1,0,0,0,0,0},
{1,1,1,0,1,0,1,0},{1,1,1,0,1,1,1,0},{1,1,1,1,1,1,1,0},
{1,1,1,1,0,0,0,0},{1,0,0,0,1,1,0,0},{1,0,0,0,0,1,0,0},
{1,0,0,0,0,0,0,0},{1,0,0,0,1,0,0,0},{1,1,0,0,1,1,0,0},
{1,1,0,0,0,1,0,0},{1,1,0,0,0,0,0,0},{1,1,0,0,1,0,0,0},
{1,1,0,1,1,1,0,0},{1,1,0,1,1,1,0,1},{1,1,0,1,0,1,0,0},
{1,1,0,1,0,1,0,1},{1,1,0,1,0,0,0,0},{1,1,0,1,1,0,0,0},
{1,0,0,1,1,1,0,0},{1,0,0,1,1,1,0,1},{1,0,0,1,0,1,0,0},
{1,0,0,1,0,1,0,1},{1,0,0,1,0,0,0,0},{1,0,1,1,0,0,0,0},
{1,0,1,1,1,0,0,0},{1,0,0,1,1,0,0,0},{1,1,0,1,0,1,1,1},
{1,1,0,1,0,1,1,0},{1,1,1,1,0,1,1,0},{1,1,1,1,0,0,1,0},
{0,1,0,0,1,1,0,0},{0,1,0,0,0,1,0,0},{0,1,0,0,0,0,0,0},
{0,1,0,0,1,0,0,0}};*)
(* Ejemplo *)
Read["L.m"];L[[12]]
Close["L.m"];Clear[L];
{1, 1, 0, 0, 1, 1, 0, 0}
(*====================   Ap 3.2.   ====================
=======================             =======================
=======================     Oct     =======================

     Octetos con componentes tomando valores 0 o 1.

Oct0:=Permutations[{0,0,0,0,0,0,0,0}]
Oct2:=Permutations[{1,1,0,0,0,0,0,0}]
Oct3:=Permutations[{1,1,1,0,0,0,0,0}]
Oct4:=Permutations[{1,1,1,1,0,0,0,0}]
Oct5:=Permutations[{1,1,1,1,1,0,0,0}]
Oct6:=Permutations[{1,1,1,1,1,1,0,0}]
Oct7:=Permutations[{1,1,1,1,1,1,1,0}]
Oct8:=Permutations[{1,1,1,1,1,1,1,1}]
Oct:=Union[Oct0,Oct1,Oct2,Oct3,Oct4,Oct5,
Oct6,Oct7,Oct8]*)
(* Ejemplo *)
Read["Oct.m"];Oct[[172]]
Close["Oct.m"];Clear[Oct];
{1, 0, 1, 0, 1, 0, 1, 1}
```

```
(*====================   Ap 3.3.   ====================
=====================              ====================
=====================      Ham     ====================

    La función Ham[u,v] tiene como entrada los
 vectores u, v y como salida su distancia Hamming

Clear[Ham]
Ham[u_,v_]:= Block[{n,d},
                n = Length[u];
                d = 0;
                For[i=1,i<=n,i++,
                  d=d+u[[i]]*(1-v[[i]])
                 +v[[i]]*(1-u[[i]])];
                Return[d];]*)

(* Ejemplo *)

Read["Ham.m"];
Ham[{1,1,1,1,1,0,0,0},{1,0,0,1,1,1,0,0}]
Close["Ham.m"];
Clear[Ham];

3

 (*====================    Cero      ====================

  Definimos la función auxiliar Cero. La función Cero
     tiene como entrada (n, m) y como salida la
            matriz nula de orden (n x m)

Clear[Cero]
Cero[n_,m_]:= Block[{A},
           A = {};
           If[m != 0,
            A = Table[0,{i,1,n},{j,1,m}],
            A = Table[0,{i,1,n}]];
           Return [A]] *)

(* Ejemplo *)

Read["Cero.m"];
MatrixForm[Cero[3,4]]
Close["Cero.m"];
Clear[Cero];

0   0   0   0

0   0   0   0

0   0   0   0
```

```
(*====================   Ap 3.4.   ====================
======================              ======================
======================    Sim       ======================

     Entrada vector de n componentes, salida su
                    simétrico

Clear[Sim]
Sim[v_] := Block[{a,b,n},
                  Read["Cero.m"];
                  a = {};
                  b = {};
                  b = v;
                  a = v;
                  n = Length[b];
                  a = Cero[n,0];
                  For[i=1,i<=n,i++,
                    If[b[[i]]==1,a[[i]]=0,
                      If[b[[i]]==0,a[[i]] = 1,0]]];
                  Close["Cero.m"];
                  Clear[Cero];
                  Return[a];]*)

(* Ejemplo *)
Read["Sim.m"];
Sim[{1,1,1,1,1,0,0,0}]
Close["Sim.m"];
Clear[Sim];
{0, 0, 0, 0, 0, 1, 1, 1}
```

```
(*====================   Ap 3.5.   ====================
======================              ====================
======================      Wa      ====================
```

Algoritmo de Aprendizaje 1

Entrada conjunto de p vectores de dimension n salida matriz de pesos cero diagonal de dimensión n x n

```
Clear[Wa]
Wa[P_]:= Block[{l,i,j,k,n,w},
                n = Length[P[[1]]];
                Read["Cero.m"];
                w = Cero[n,n];
                l = Length[P];
                For[i=1,i<=l,i++,
                 For[j=1,j<=n,j++,
                   For[k=1,k<=n,k++,
                    If[j==k,w[[j,k]]=0,
                    If[P[[i]][[j]]==P[[i]][[k]]==1,
                     w[[j,k]] = w[[j,k]]+1,
                     If[P[[i]][[j]]==P[[i]][[k]]==0,
                       w[[j,k]] = w[[j,k]]-1,0]]]]];
                 Close["Cero.m"];
                 Clear[Cero];
               Return [w]]*)
```

(* Ejemplo: Matriz de pesos resultado de aplicar el algoritmo de aprendizaje I a el conjunto L, la matriz resultante la guardamos en W.m *)

```
Read["L.m"];Read["Wa.m"];
Wa[L]
Close["Wa.m"];Close["L.m"];Clear[Wa,L]
{{0, 21, 7, 16, 12, 16, 4, 1},

 {21, 0, -1, 8, 4, 8, -4, -7},

 {7, -1, 0, -6, -10, -6, -18, -21},

 {16, 8, -6, 0, -1, 3, -9, -12},

 {12, 4, -10, -1, 0, -1, -13, -16},

 {16, 8, -6, 3, -1, 0, -9, -12},

 {4, -4, -18, -9, -13, -9, 0, -24},

 {1, -7, -21, -12, -16, -12, -24, 0}}
```

```
(*====================   Ap 3.6.   ====================
======================             ====================
======================      Wb     ====================

            Algoritmo de Aprendizaje 2

Entrada conjunto de p vectores  y parámetro a, salida
 matriz de pesos cero diagonal de dimensión n x n

Clear[Wp]
Wp[P_,a_]:= Block[{l,i,j,k,n,w,n0,n1},
               n = Length[P[[1]]];
               Read["Cero.m"];
               w = Cero[n,n];
               l = Length[P];
               n1=0;
               n0=0;
               For[i=1,i<=l,i++,
                n1=P[[i]].P[[i]];
                n0=n-n1;
                For[j=1,j<=n,j++,
                  For[k=1,k<=n,k++,
                   If[j==k,w[[j,k]]=0,
                    If[P[[i]][[j]]==P[[i]][[k]]==1,
                     w[[j,k]] = w[[j,k]]+1+a*n0,
                     If[P[[i]][[j]]==P[[i]][[k]]==0,
                      w[[j,k]] = w[[j,k]]-1-a*n1,0]]]]];
               Close["Cero.m"];
               Clear[Cero];
             Return [w]]*)
(* Ejemplo *)
Read["Wp.m"];Read["L.m"];
Wp[L,1]
Close["Wp.m"];Close["L.m"];Clear[Wp,L]
{{0, 95, 36, 80, 60, 75, 16, 7},

 {95, 0, -2, 36, 24, 39, -20, -27},

 {36, -2, 0, -15, -43, -20, -79, -82},

 {80, 36, -15, 0, 3, 16, -33, -48},

 {60, 24, -43, 3, 0, 0, -53, -68},

 {75, 39, -20, 16, 0, 0, -36, -49},

 {16, -20, -79, -33, -53, -36, 0, -96},

 {7, -27, -82, -48, -68, -49, -96, 0}}
```

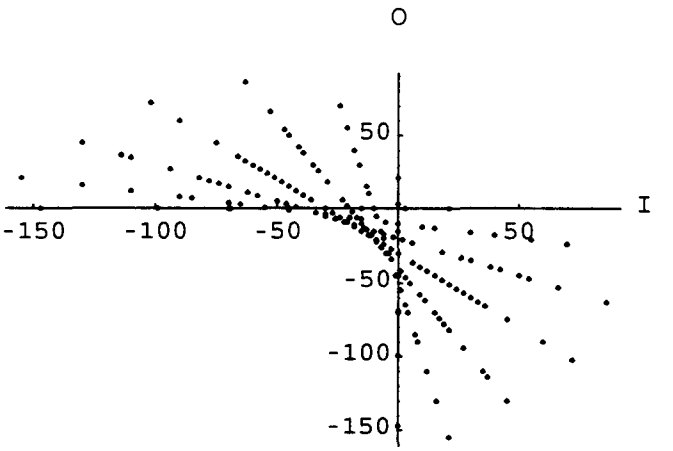
```
(*====================   Ap. 4.1. ====================
======================             ====================
======================    ParIO    ====================

Funcion para hallar el par de energía asociado a un
 patron o estado de la red: los argumemtos de la
  función son la matriz de pesos y el vector v,
      la salida será el parde energía.

Clear[ParIO]
ParIO[v_,A_]:= Block[{p,s},
               Read["Sim.m"];
               Read["Cero.m"];
               p = Cero[2,0];
               s = Sim[v];
               p[[1]]=1/2v.A.v;
               p[[2]]=1/2s.A.s;
               Close["Sim.m"];
               Close["Cero.m"];
               Clear[Cero,Sim];
               Return [p]]*)

(* Ejemplo *)

Read["W.m"];Read["ParIO.m"];
ParIO[{1,1,1,1,1,0,0,0},W]
Close["W.m"];Close["ParIO.m"];Clear[W,ParIO];

{50, -45}

(*===============  PriIO  SegIO  ====================

Funcion que halla las componentes del par de energía

Clear[PriIO]
PriIO[v_,A_]:= Block[{p},
               p=1/2v.A.v;
               Return [p];]

Clear[SegIO]
SegIO[v_,A_]:= Block[{s},
               Read["Sim.m"];
               s = Sim[v];
               p=1/2s.A.s;
               Return [p];]*)

(* Ejemplo *)

Read["W.m"];Read["PriIO.m"];Read["SegIO.m"];
PriIO[{1,1,1,1,1,0,0,0},W]
SegIO[{1,1,1,1,1,0,0,0},W]
Close["W.m"];Close["PriIO.m"];Close["SegIO.m"];
Clear[W,PriIO,SegIO];

50

-45
```

```
(*================== TotIO   EquIO ====================

  Funciones auxiliares para hallar la suma de todos los
    valores de las aristas del Grafo Resultante y la
  suma de todos los valores en las aristas intermedias

Clear[TotIO]
TotIO[A_]:= Block[{E,n,w},
                n = Length[A[[1]]];
                Read["Uno.m"];
                w = Uno[n,0];
                E = 1/2w.A.w;
                Return [E]]
Clear[EquIO]
EquIO[v_,A_]:=  Block[{T,E,s},
                Read["TotIO.m"];
                Read["Sim.m"];
                s = Sim[v];
                T=TotIO[A];
                E=T-1/2v.A.v-1/2s.A.s;
                Return[E]]*)
(* Ejemplo *)
Read["W.m"];Read["EquIO.m"];Read["TotIO.m"];
TotIO[W]
EquIO[{1,1,1,1,1,0,0,0},W]
Close["W.m"];Close["EquIO.m"];Close["TotIO.m"];
Clear[W,TotIO,EquIO];
-70
-75
```

```
(*====================   Ap. 4.2. ====================
=====================             =====================
=====================   ParesIO   =====================

 Primero generamos una lista con todos los pares de
  energía correspondientes a un conjunto dado de
 estados, la función ParesIO tiene como argumentos
 un conjunto de patrones L y una matriz de pesos W
   y como salida se obtiene la lista de pares de
      energía de dicho conjunto de estados

Clear[ParesIO]
ParesIO[L_,A_]:= Block[{p,n},
                 Read["ParIO.m"];
                 n = Length[L];
                 p= Table[ParIO[L[[i]],A],{i,1,n}];
                 Clear["ParIO.m"];
                 Return [p]]*)
(* Ejemplo *)
Read["Oct3.m"];Read["W.m"];Read["ParesIO.m"];
ParesIO[Oct3,W]
Close["ParesIO.m"];Close["Oct3.m"];Close["W.m"];
Clear[Oct3,W,ParesIO];
{{27, -94}, {45, -130}, {37, -114}, {45, -130},

 {21, -82}, {15, -70}, {17, -74}, {9, -58},

 {17, -74}, {-7, -26}, {-13, -14}, {27, -94},

 {35, -110}, {11, -62}, {5, -50}, {27, -94},

 {3, -46}, {-3, -34}, {11, -62}, {5, -50}, {-19, -2},

 {1, -42}, {-7, -26}, {1, -42}, {-23, 6}, {-29, 18},

 {11, -62}, {19, -78}, {-5, -30}, {-11, -18},

 {11, -62}, {-13, -14}, {-19, -2}, {-5, -30},

 {-11, -18}, {-35, 30}, {-17, -6}, {-9, -22},

 {-33, 26}, {-39, 38}, {-17, -6}, {-41, 42},

 {-47, 54}, {-33, 26}, {-39, 38}, {-63, 86},

 {1, -42}, {-23, 6}, {-29, 18}, {-15, -10}, {-21, 2},

 {-45, 50}, {-23, 6}, {-29, 18}, {-53, 66}, {-45, 50}}
```

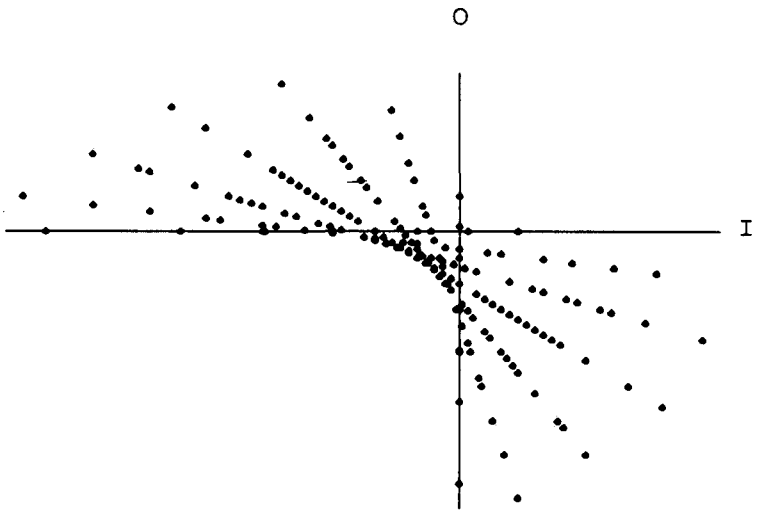
```
(*===============      ParposIO     ====================

La función ParposIO es exactamente igual que la fun-
ción ParesIO, únicamente que nada más que se obtie-
nen los pares de energía con la primera componente
positiva; esto nos simplificará las gráficas, ya que
veremos solo aquellos con la primera componente pos
itiva


Clear[ParposIO]
ParposIO[L_,A_]:= Block[{p,n,1,j},
                  Read["Cero.m"];
                  Read["ParIO.m"];
                  Read["PriIO.m"];
                  n = Length[L];
                  j=0;
                  For[i=1,i<=n,++i,
                   If[PriIO[L[[i]],A]>=0,j=j+1,]];
                    1=Cero[j,2];
                  j=1;
                  For[k=1,k<=n,++k,
                   If[PriIO[L[[k]],A]>=0,
                    1[[j]]=ParIO[L[[k]],A];j=j+1,]];
                  Close["Cero.m"];
                  Close["ParIO.m"];
                  Close["PriIO.m"];
                  Clear[Cero,ParIO,PriIO];
                 Return [1]]*)
(* Ejemplo *)

Read["Oct2.m"];Read["W.m"];Read["ParposIO.m"];
ParposIO[Oct2,W]
Close["ParposIO.m"];Close["Oct2.m"];Close["W.m"];
Clear[Oct2,ParposIO,W]
{{21, -155}, {7, -85}, {16, -130}, {12, -110},

 {16, -130}, {4, -70}, {1, -55}, {8, -90}, {4, -70},

 {8, -90}, {3, -65}}
```

```
(*===============      PuntosIO      ====================

La función PuntosIO[X_,P_,n_], representa gráfica-
mente en un plano de ejes (I, O), los puntos del
conjunto X repecto a la matriz de pesos W con un
grosor n.

Clear[PuntosIO]
PuntosIO[X_,P_,n_]:= Block[{},
                Read["ParesIO.m"];
                ListPlot[ParesIO[X,P],
                PlotStyle->{PointSize[n]},
                FrameTicks->None,
                AxesLabel->{"I","O"}]]*)
(* Ejemplo *)
Read["W.m"]; Read["Oct.m"];Read["PuntosIO.m"];
PuntosIO[Oct,W,0.006]
Close["W.m"];Close["Oct.m"];Close["PuntosIO.m"];
Clear[W,Oct,PuntosIO];
```



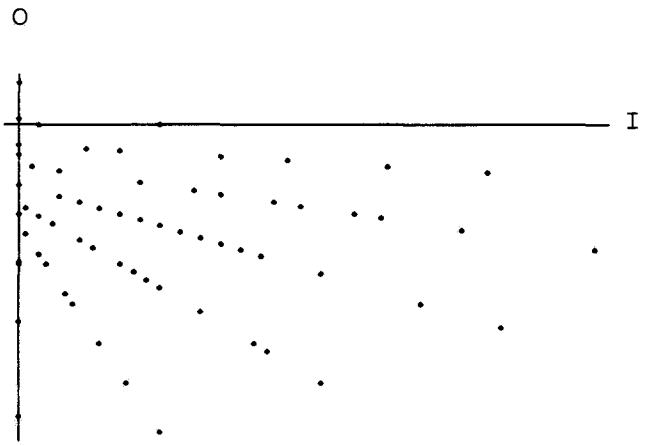
-Graphics-

```
(*===============      Punto2IO    ====================

    La misma función anterior pero sin ticks

Clear[Punto2IO]
Punto2IO[X_,P_,n_]:= Block[{},
                Read["ParesIO.m"];
                ListPlot[ParesIO[X,P],
                PlotStyle->{PointSize[n]},
                FrameTicks->None,
                Ticks->None,
                AxesLabel->{"I","O"}]]*)

(* Ejemplo *)
Read["W.m"];
Read["Oct.m"];
Read["Punto2IO.m"];
Punto2IO[Oct,W,0.006]
Close["W.m"];
Close["Oct.m"];
Close["Punto2IO.m"];
```



-Graphics-

```
(*===============      Punto3IO    ====================

La misma función anterior pero sin ticks y solo los
                de abcisa positiva

Clear[Punto3IO]
Punto3IO[X_,P_,n_]:= Block[{},
                 Read["ParposIO.m"];
                 ListPlot[ParposIO[X,P],
                 PlotStyle->{PointSize[n]},
                 FrameTicks->None,
                 Ticks->None,
                 AxesLabel->{"I","O"}]]*)

(* Ejemplo *)
Read["W.m"];
Read["Oct.m"];
Read["Punto3IO.m"];
Punto3IO[Oct,W,0.006]
Close["W.m"];
Close["Oct.m"];
Close["Punto3IO.m"];
```



-Graphics-

```
(*===============        Listar    ====================

 Dado un conjunto de patrones, lista los diferentes

Clear[Listar]
Listar[G_]:= Block[{m,n,j,k,l,A,F},
        Read["Cero.m"];
        F=Sort[G];
        n=Length[F];
        m=Length[F[[1]]];
        l=0;
        A={};
        j=1;
        k=1;
        While[k <= n,
        (Do[
        If[F[[i]]==F[[j]],k=k+1,],{i,j,n}];
        Print[F[[j]]];
        l=l+1;
        j= k)];
        A=Cero[l,m];
        l=0;
        j=1;
        k=1;
        While[k <= n,
        (Do[
        If[F[[i]]==F[[j]],k=k+1,],{i,j,n}];
        l=l+1;
        A[[l]]=F[[j]];
        j= k)];
        Close["Cero.m"];
        Clear[Cero];
        Return[A]]*)
(* Ejemplo: Listar patrones de Oct2 *)
```

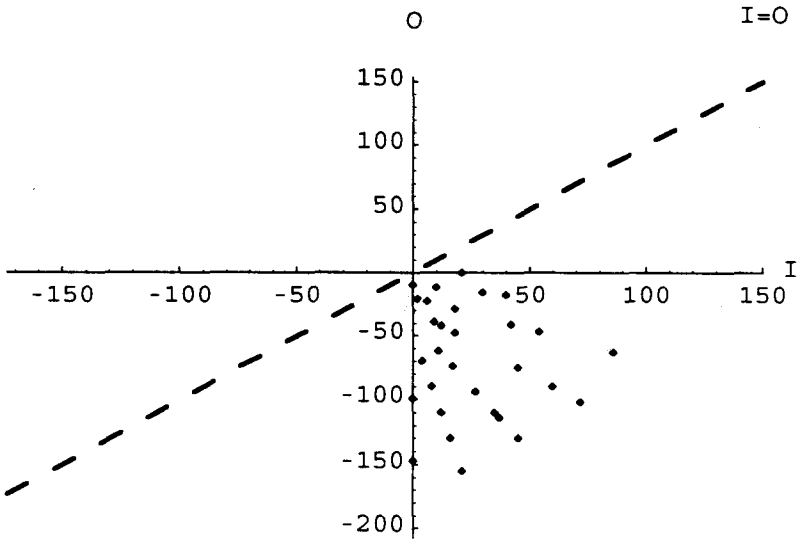
```
Read["Oct2.m"];
Read["Listar.m"];
Listar[Oct2];
Close["Oct2.m"];
Close["Listar.m"];
Clear[Listar,Oct2];
```

```
{0, 0, 0, 0, 0, 0, 1, 1}
{0, 0, 0, 0, 0, 1, 0, 1}
{0, 0, 0, 0, 0, 1, 1, 0}
{0, 0, 0, 0, 1, 0, 0, 1}
{0, 0, 0, 0, 1, 0, 1, 0}
{0, 0, 0, 0, 1, 1, 0, 0}
{0, 0, 0, 1, 0, 0, 0, 1}
{0, 0, 0, 1, 0, 0, 1, 0}
{0, 0, 0, 1, 0, 1, 0, 0}
{0, 0, 0, 1, 1, 0, 0, 0}
{0, 0, 1, 0, 0, 0, 0, 1}
{0, 0, 1, 0, 0, 0, 1, 0}
{0, 0, 1, 0, 0, 1, 0, 0}
{0, 0, 1, 0, 1, 0, 0, 0}
{0, 0, 1, 1, 0, 0, 0, 0}
{0, 1, 0, 0, 0, 0, 0, 1}
{0, 1, 0, 0, 0, 0, 1, 0}
{0, 1, 0, 0, 0, 1, 0, 0}
{0, 1, 0, 0, 1, 0, 0, 0}
{0, 1, 0, 1, 0, 0, 0, 0}
{0, 1, 1, 0, 0, 0, 0, 0}
{1, 0, 0, 0, 0, 0, 0, 1}
{1, 0, 0, 0, 0, 0, 1, 0}
{1, 0, 0, 0, 0, 1, 0, 0}
{1, 0, 0, 0, 1, 0, 0, 0}
{1, 0, 0, 1, 0, 0, 0, 0}
{1, 0, 1, 0, 0, 0, 0, 0}
{1, 1, 0, 0, 0, 0, 0, 0}
```

```
(*===============      Pinta     ====================

 Algoritmo que teniendo como entrada todos los
pares de energía del conjunto F y los del conjunto T,
  ambos respecto a la matriz de pesos A, con
diferente grosor, listando los de mayor grosor

Clear[Pinta]
Pinta[F_,T_,A_]:= Block[{},
        Read["Listar.m"];
        Listar[F];
        Close["Listar.m"];
        Clear["Listar.m"];
        Read["PuntosIO.m"];
        Show[PuntosIO[F,A,.007],PuntosIO[T,A,.001],
        Graphics[{Dashing[{0.03,0.04}],
        Line[{{-300,-300},{300,300}}],
        Text["I=O",{150,200}]
        }],
        DisplayFunction:>$DisplayFunction];
        Close["PuntosIO.m"];
        Clear["PuntosIO.m"];
        Close["ParesIO.m"];
        Clear["ParesIO.m"]]*)

(* Ejemplo: Listar y representar los patrones de L
         --  ver página siguiente  --              *)
```

```
Read["Pinta.m"];Read["Oct.m"];Read["L.m"];Read["W.m"];
Pinta[L,Oct,W]
Close["Pinta.m"];Close["Oct.m"];Close["L.m"];
Close["W.m"];Clear[Pinta,Oct,W,L];
```

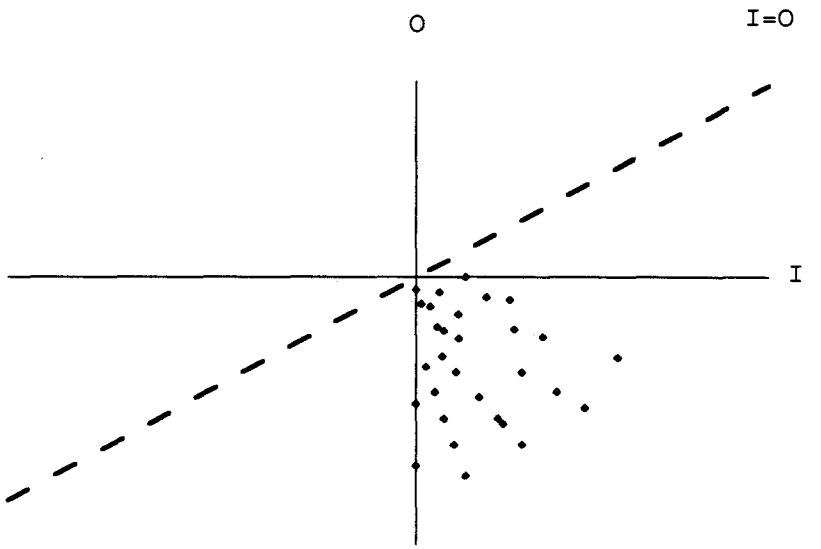
```
{0, 1, 0, 0, 0, 0, 0, 0}
{0, 1, 0, 0, 0, 1, 0, 0}
{0, 1, 0, 0, 1, 0, 0, 0}
{0, 1, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 0, 0, 0, 0, 0}
{1, 0, 0, 0, 0, 1, 0, 0}
{1, 0, 0, 0, 1, 0, 0, 0}
{1, 0, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 1, 0, 0, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 1}
{1, 0, 0, 1, 1, 0, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 1}
{1, 0, 1, 1, 0, 0, 0, 0}
{1, 0, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 0, 0, 0, 0, 0}
{1, 1, 0, 0, 0, 1, 0, 0}
{1, 1, 0, 0, 1, 0, 0, 0}
{1, 1, 0, 0, 1, 1, 0, 0}
{1, 1, 0, 1, 0, 0, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 1}
{1, 1, 0, 1, 0, 1, 1, 0}
{1, 1, 0, 1, 0, 1, 1, 1}
{1, 1, 0, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 1}
{1, 1, 1, 0, 0, 0, 0, 0}
{1, 1, 1, 0, 0, 0, 1, 0}
{1, 1, 1, 0, 0, 1, 0, 0}
{1, 1, 1, 0, 1, 0, 1, 0}
{1, 1, 1, 0, 1, 1, 1, 0}
{1, 1, 1, 1, 0, 0, 0, 0}
{1, 1, 1, 1, 0, 0, 1, 0}
{1, 1, 1, 1, 0, 1, 1, 0}
{1, 1, 1, 1, 1, 1, 1, 0}
```



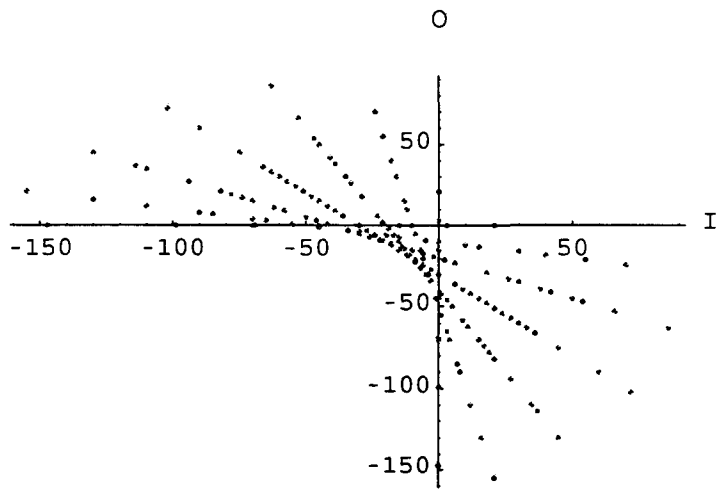
```
(*===============      Pinta2     ====================

  Lo mismo que Pinta, pero sin marcas en los ejes.

Clear[Pinta2]
Pinta2[F_,T_,A_]:= Block[{},
        Read["Listar.m"];
        Listar[F];
        Close["Listar.m"];
        Clear["Listar.m"];
        Read["Punto2IO.m"];
        Show[Punto2IO[F,A,.007],Punto2IO[T,A,.001],
        Graphics[{Dashing[{0.03,0.04}],
        Line[{{-300,-300},{300,300}}],
        Text["I=O",{150,200}]
        }],
        DisplayFunction:>$DisplayFunction];
        Close["Punto2IO.m"];
        Clear["Punto2IO.m"]]*)

(* Ejemplo *)
```

```
Read["Pinta2.m"];Read["Oct.m"];Read["L.m"];
Read["W.m"];
Pinta2[L,Oct,W]
Close["Pinta2.m"];Close["Oct.m"];Close["L.m"];
Close["W.m"];Clear[Pinta2,Oct,W,L];
```

```
{0, 1, 0, 0, 0, 0, 0, 0}
{0, 1, 0, 0, 0, 1, 0, 0}
{0, 1, 0, 0, 1, 0, 0, 0}
{0, 1, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 0, 0, 0, 0, 0}
{1, 0, 0, 0, 0, 1, 0, 0}
{1, 0, 0, 0, 1, 0, 0, 0}
{1, 0, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 1, 0, 0, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 1}
{1, 0, 0, 1, 1, 0, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 1}
{1, 0, 1, 1, 0, 0, 0, 0}
{1, 0, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 0, 0, 0, 0, 0}
{1, 1, 0, 0, 0, 1, 0, 0}
{1, 1, 0, 0, 1, 0, 0, 0}
{1, 1, 0, 0, 1, 1, 0, 0}
{1, 1, 0, 1, 0, 0, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 1}
{1, 1, 0, 1, 0, 1, 1, 0}
{1, 1, 0, 1, 0, 1, 1, 1}
{1, 1, 0, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 1}
{1, 1, 1, 0, 0, 0, 0, 0}
{1, 1, 1, 0, 0, 0, 1, 0}
{1, 1, 1, 0, 0, 1, 0, 0}
{1, 1, 1, 0, 1, 0, 1, 0}
{1, 1, 1, 0, 1, 1, 1, 0}
{1, 1, 1, 1, 0, 0, 0, 0}
{1, 1, 1, 1, 0, 0, 1, 0}
{1, 1, 1, 1, 0, 1, 1, 0}
{1, 1, 1, 1, 1, 1, 1, 0}
```



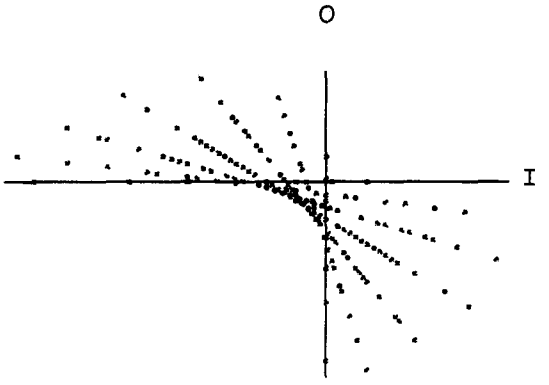
```
Clear[RojosIO]
RojosIO[X_,P_,n_]:= Block[{},
                  Read["ParesIO.m"];
                  ListPlot[ParesIO[X,P],
                  PlotStyle->{PointSize[n],RGBColor[1,0,0]},
                  FrameTicks->None,
                  AxesLabel->{"I","O"}]]

Save["RojosIO.m",RojosIO]
Read["W.m"]; Read["Oct.m"];Read["RojosIO.m"];
RojosIO[Oct,W,0.006]
Close["W.m"];Close["Oct.m"];Close["RojosIO.m"];
Clear[W,Oct,RojosIO];
```



-Graphics-

```
Clear[Rojo2IO]
Rojo2IO[X_,P_,n_]:= Block[{},
                  Read["ParesIO.m"];
                  ListPlot[ParesIO[X,P],
                  PlotStyle->{PointSize[n],RGBColor[1,0,0]},
                  FrameTicks->None,
                  Ticks->None,
                  AxesLabel->{"I","O"}]]

Save["Rojo2IO.m",Rojo2IO]
```

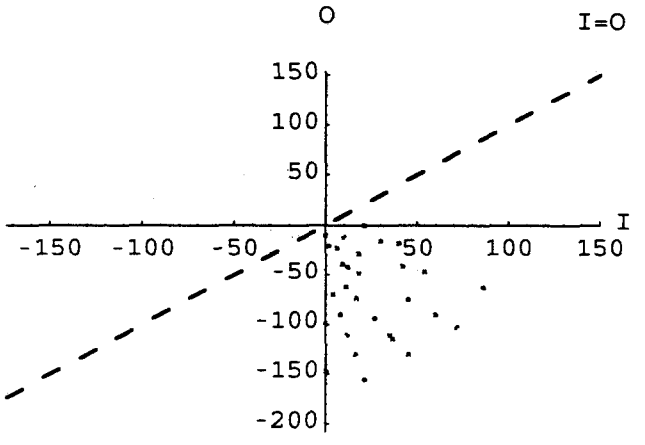
```
Read["W.m"];
Read["Oct.m"];
Read["Rojo2IO.m"];
Rojo2IO[Oct,W,0.006]
Close["W.m"];
Close["Oct.m"];
Close["Rojo2IO.m"];
```



```
Clear[Pintar]
Pintar[F_,T_,A_]:= Block[{},
        Read["Listar.m"];
        Listar[F];
        Close["Listar.m"];
        Clear["Listar.m"];
        Read["PuntosIO.m"];
        Read["RojosIO.m"];
        Show[RojosIO[F,A,.006],PuntosIO[T,A,.001],
        Graphics[{Dashing[{0.03,0.04}],
        Line[{{-300,-300},{300,300}}],
        Text["I=O",{150,200}]
        }],
        DisplayFunction:>$DisplayFunction];
        Close["RojosIO.m"];
        Clear["RojosIO.m"];
        Close["PuntosIO.m"];
        Clear["PuntosIO.m"];
        Close["ParesIO.m"];
        Clear["ParesIO.m"]]

Save["Pintar.m",Pintar]
```

```
Read["Pintar.m"];Read["Oct.m"];Read["L.m"];Read["W.m"];
Pintar[L,Oct,W]
Close["Pintar.m"];Close["Oct.m"];Close["L.m"];
Close["W.m"];Clear[Pintar,Oct,W,L];
```

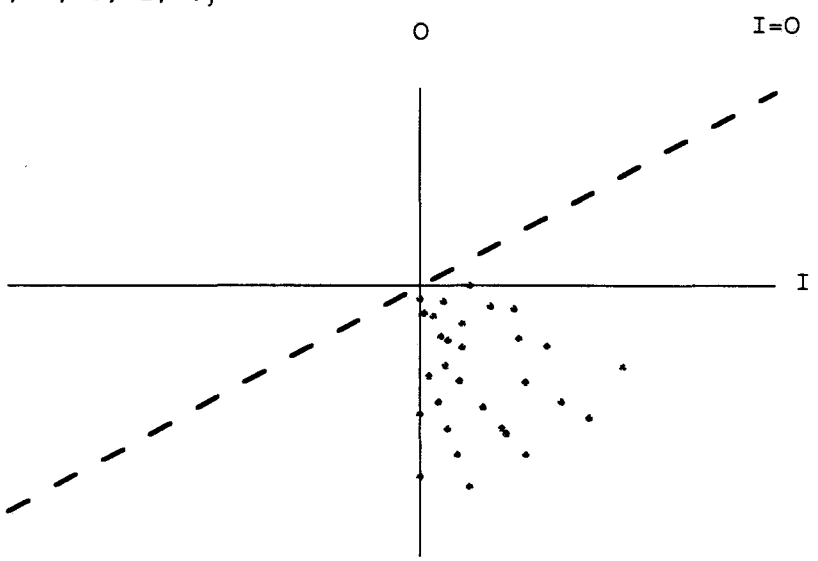
```
{0, 1, 0, 0, 0, 0, 0, 0}
{0, 1, 0, 0, 0, 1, 0, 0}
{0, 1, 0, 0, 1, 0, 0, 0}
{0, 1, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 0, 0, 0, 0, 0}
{1, 0, 0, 0, 0, 1, 0, 0}
{1, 0, 0, 0, 1, 0, 0, 0}
{1, 0, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 1, 0, 0, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 1}
{1, 0, 0, 1, 1, 0, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 1}
{1, 0, 1, 1, 0, 0, 0, 0}
{1, 0, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 0, 0, 0, 0, 0}
{1, 1, 0, 0, 0, 1, 0, 0}
{1, 1, 0, 0, 1, 0, 0, 0}
{1, 1, 0, 0, 1, 1, 0, 0}
{1, 1, 0, 1, 0, 0, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 1}
{1, 1, 0, 1, 0, 1, 1, 0}
{1, 1, 0, 1, 0, 1, 1, 1}
{1, 1, 0, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 1}
{1, 1, 1, 0, 0, 0, 0, 0}
{1, 1, 1, 0, 0, 0, 1, 0}
{1, 1, 1, 0, 0, 1, 0, 0}
{1, 1, 1, 0, 1, 0, 1, 0}
{1, 1, 1, 0, 1, 1, 1, 0}
{1, 1, 1, 1, 0, 0, 0, 0}
{1, 1, 1, 1, 0, 0, 1, 0}
{1, 1, 1, 1, 0, 1, 1, 0}
{1, 1, 1, 1, 1, 1, 1, 0}
```



```
Clear[Pintar2]
Pintar2[F_,T_,A_]:= Block[{},
        Read["Listar.m"];
        Listar[F];
        Close["Listar.m"];
        Clear["Listar.m"];
        Read["Punto2IO.m"];
        Read["Rojo2IO.m"];
        Show[Rojo2IO[F,A,.006],Punto2IO[T,A,.001],
        Graphics[{Dashing[{0.03,0.04}],
        Line[{{-300,-300},{300,300}}],
        Text["I=O",{150,200}]
        }],
        DisplayFunction:>$DisplayFunction];
        Close["Punto2IO.m"];
        Clear["Punto2IO.m"];
        Close["Rojo2IO.m"];
        Clear["Rojo2IO.m"]]

Save["Pintar2.m",Pintar2]
```

```
Read["Pintar2.m"];Read["Oct.m"];Read["L.m"];
Read["W.m"];
Pintar2[L,Oct,W]
Close["Pintar2.m"];Close["Oct.m"];Close["L.m"];
Close["W.m"];Clear[Pintar2,Oct,W,L];
```

```
{0, 1, 0, 0, 0, 0, 0, 0}
{0, 1, 0, 0, 0, 1, 0, 0}
{0, 1, 0, 0, 1, 0, 0, 0}
{0, 1, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 0, 0, 0, 0, 0}
{1, 0, 0, 0, 0, 1, 0, 0}
{1, 0, 0, 0, 1, 0, 0, 0}
{1, 0, 0, 0, 1, 1, 0, 0}
{1, 0, 0, 1, 0, 0, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 0}
{1, 0, 0, 1, 0, 1, 0, 1}
{1, 0, 0, 1, 1, 0, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 0}
{1, 0, 0, 1, 1, 1, 0, 1}
{1, 0, 1, 1, 0, 0, 0, 0}
{1, 0, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 0, 0, 0, 0, 0}
{1, 1, 0, 0, 0, 1, 0, 0}
{1, 1, 0, 0, 1, 0, 0, 0}
{1, 1, 0, 0, 1, 1, 0, 0}
{1, 1, 0, 1, 0, 0, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 1}
{1, 1, 0, 1, 0, 1, 1, 0}
{1, 1, 0, 1, 0, 1, 1, 1}
{1, 1, 0, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 1}
{1, 1, 1, 0, 0, 0, 0, 0}
{1, 1, 1, 0, 0, 0, 1, 0}
{1, 1, 1, 0, 0, 1, 0, 0}
{1, 1, 1, 0, 1, 0, 1, 0}
{1, 1, 1, 0, 1, 1, 1, 0}
{1, 1, 1, 1, 0, 0, 0, 0}
{1, 1, 1, 1, 0, 0, 1, 0}
{1, 1, 1, 1, 0, 1, 1, 0}
{1, 1, 1, 1, 1, 1, 1, 0}
```



```
(*====================   Ap. 4.3. ====================
======================             ======================
======================      ui     ======================

Matrices tetraédricas básicas de dimensión n, todos
los elementos de la matriz son cero excepto la fila
y columna k-ésima que son uno

ui[n_,k_] := Block[{a},
        a = {};
        Read["Cero.m"];
        a = Cero[n,n];
        For[i=1,i<=n,i++,
          a[[i,k]]=1];
        For[j=1,j<=n,j++,
          a[[k,j]]=1];
        a[[k,k]]=0;
        Close[Cero];
        Clear[Cero];
        Return[a]]*)

(* Ejemplo *)
Read["ui.m"];
ui[8,3]
Close["ui.m"];Clear[ui];
{{0, 0, 1, 0, 0, 0, 0, 0}, {0, 0, 1, 0, 0, 0, 0, 0},

 {1, 1, 0, 1, 1, 1, 1, 1}, {0, 0, 1, 0, 0, 0, 0, 0},

 {0, 0, 1, 0, 0, 0, 0, 0}, {0, 0, 1, 0, 0, 0, 0, 0},

 {0, 0, 1, 0, 0, 0, 0, 0}, {0, 0, 1, 0, 0, 0, 0, 0}}
```

```
(*====================   Ap. 4.4.  ====================
======================              ====================
======================      H       ====================

    Matriz de coeficientes del sistema cuando
            la dimensión es n

Clear[H];
H[n_] := Block[{a},
         Read["Cero.m"];
         a = Cero[n,n];
         For[i=2,i<=n,i++,
           a[[i,1]]=1;
           a[[i,i]]=1];
         a[[1,2]]=1;
         a[[1,n]]=1;
         Close["Cero.m"];
         Clear[Cero];
         Return[a]]*)
(* Ejemplo *)
Read["H.m"];
H[8]
Close["H.m"];Clear[H];
{{0, 1, 0, 0, 0, 0, 0, 1}, {1, 1, 0, 0, 0, 0, 0, 0},

 {1, 0, 1, 0, 0, 0, 0, 0}, {1, 0, 0, 1, 0, 0, 0, 0},

 {1, 0, 0, 0, 1, 0, 0, 0}, {1, 0, 0, 0, 0, 1, 0, 0},

 {1, 0, 0, 0, 0, 0, 1, 0}, {1, 0, 0, 0, 0, 0, 0, 1}}

(* Verificamoe que efectivamente el determinante
 de H es igual a -2, para ello lo verificamos en
algunos casos, por ejemplo en los casos de ser la
dimensión de estas matrices igual a 3,4,...7 *)
Read["H.m"];
Do[Print[Det[H[i]]],{i,3,7}]
Close["H.m"];Clear[H];
-2
-2
-2
-2
-2
```

```
(*====================   Ap. 4.5. ====================
======================              ====================
======================      P       ====================

     Obtención de parámetros que definen la
              matriz de pesos

P[A_] := Block[{a},
         n = Length[A[[1]]];
         Read["Cero.m"];
         a = Cero[n,0];
         For[i=1,i<=n-2,i++,
         a[[i]]= (A[[i,i+1]]+A[[i,i+2]]-A[[i+1,i+2]])/2];
         a[[n-1]] = -(A[[1,2]]-A[[1,n-1]]-A[[2,n-1]])/2;
         a[[n]] = -(A[[1,2]]-A[[1,n]]-A[[2,n]])/2;
         Close["Cero.m"];
         Clear[Cero];
         Return[a]]*)

(*Ejemplo: Parámetros definidos por la matriz de
pesos definida en Ap.3.5. *)

Read["W.m"];
Read["P.m"];
P[W]
Close["W.m"];
Close["P.m"];
Clear[W,P];
```

$$\left\{\frac{29}{2}, \frac{13}{2}, -\left(\frac{15}{2}\right), \frac{3}{2}, -\left(\frac{5}{2}\right), \frac{3}{2}, -\left(\frac{21}{2}\right), -\left(\frac{27}{2}\right)\right\}$$

```
(* comprobamos que la solución del sistema 4.31. es
efectivamente la dada anteriormente *)

Solve[{
p2+p8 == -7,
p1+p2 == 21,
p1+p3 == 7,
p1+p4 == 16,
p1+p5 == 12,
p1+p6 == 16,
p1+p7 == 4,
p1+p8 == 1},
{p1,p2,p3,p4,p5,p6,p7,p8}]
```

$$\{\{p3 \to -\frac{15}{2},\ p4 \to -\frac{3}{2},\ p5 \to -\frac{5}{2},\ p6 \to -\frac{3}{2},$$

$$p7 \to -\frac{21}{2},\ p2 \to \frac{13}{2},\ p8 \to -\frac{27}{2},\ p1 \to \frac{29}{2}\}\}$$

```
(* Se comprueba que efectivamente

 W=P[W][[1]]*ui[8,1]+..+P[W][[8]]*ui[8,8]*)

Read["W.m"];Read["P.m"];Read["H.m"];Read["ui.m"];
W==
P[W][[1]]*ui[8,1]+
P[W][[2]]*ui[8,2]+
P[W][[3]]*ui[8,3]+
P[W][[4]]*ui[8,4]+
P[W][[5]]*ui[8,5]+
P[W][[6]]*ui[8,6]+
P[W][[7]]*ui[8,7]+
P[W][[8]]*ui[8,8]
Close["W.m"];Close["P.m"];Close["H.m"];Clear[W];
Close["ui.m"];
True
```

```
(*====================   Ap. 4.6.  ====================
======================              ======================
======================      K       ======================

        Constante K asociada a el vector p

K[p_]:= (Sum[p[[i]],{i,1,Length[p]}])*(Length[p]-1)*)

(* Ejemplo *)
Read["K.m"];Read["W.m"];Read["P.m"];p = P[W];
K[p]
Close["W.m"];Close["P.m"];Close["K.m"];
Clear[p];Clear[W];
-70
```

```
(*====================   Ap. 4.7. ====================
======================              ====================
======================      r       ====================

                    Recta i-esima ("i unos")

(Los parametros de entrada son el vector de parame
tros asociado a la matroz de pesos y la clase i, la
salida es los tres coeficientes a, b, c que definen
la recta ax+by+c=0)

Clear[r,p,i];
r[p_,i_]:= Block[{n,n1,n0,d,,nd,k,m},
        n= Length[p];
        m=n-1;
        n1=i;
        n0=n-i;
        Read["Cero.m"];
        d=Cero[2,0];
        nd=Cero[3,0];
        Read["K.m"];
        k=K[p];
        If[i==0,d[[1]]=0;d[[2]]=k;Return[d]];
        If[i==1,nd[[1]]=1;nd[[2]]=0;nd[[3]]=0;
        Return[nd]];
        If[i==n,d[[1]]=k;d[[2]]=0;Return[d]];
        If[i==m,nd[[1]]=0;nd[[2]]=1;nd[[3]]=0;
        Return[nd]];
        If[i>1, If[ i<m,
        nd[[1]]=1/(n1-1);
        nd[[2]]=1/(n0-1);
        nd[[3]]=-k/(n-1);
        Close["Cero.m"];
        Clear[Cero];
        Return[nd]]]*)
(* Ejemplo *)
Read["r.m"];Read["P.m"];Read["W.m"];p=P[W];
r[p,3]
Close["W.m"];Close["P.m"];Close["r.m"];Clear[p];
Clear[W];
 1  1
{-, -, 10}
 2  4
```

```
(*====================   Ap. 4.8. ====================
=====================             ====================
=============   Uno (fumción auxiliar)  =============

      Vector de parámetros transformado

Clear[Uno]
Uno[n_,m_]:= Block[{A},
           A = {};
           If[m != 0,
           A = Table[1,{i,1,n},{j,1,m}],
           A = Table[1,{i,1,n}]];
           Return [A]]*)

(*===============          Q       ====================

  Dada una matriz de pesos hallamos el vector
 de parámetros correspondiente a la matriz de
            pesos transformada

Clear[Q,A]
Q[A_]:= Block[{n,q,p,i,k},
        Read["P.m"];
        Read["K.m"];
        n=Length[A];
        Read["Cero.m"];
        q=Cero[n,0];
        p=P[A];
        k=K[P[A]];
        For[i=1,i<=n,i++,
        q[[i]]=p[[i]]-(k/(n(n-1)))];
        Clear["P.m"];Clear["K.m"];Clear["Cero.m"];
        Return[q]]*)
(* Ejemplo *)
Read["Q.m"];Read["W.m"];
Q[W]
Close["Q.m"];Close["W.m"];
Clear[Q,W];
```

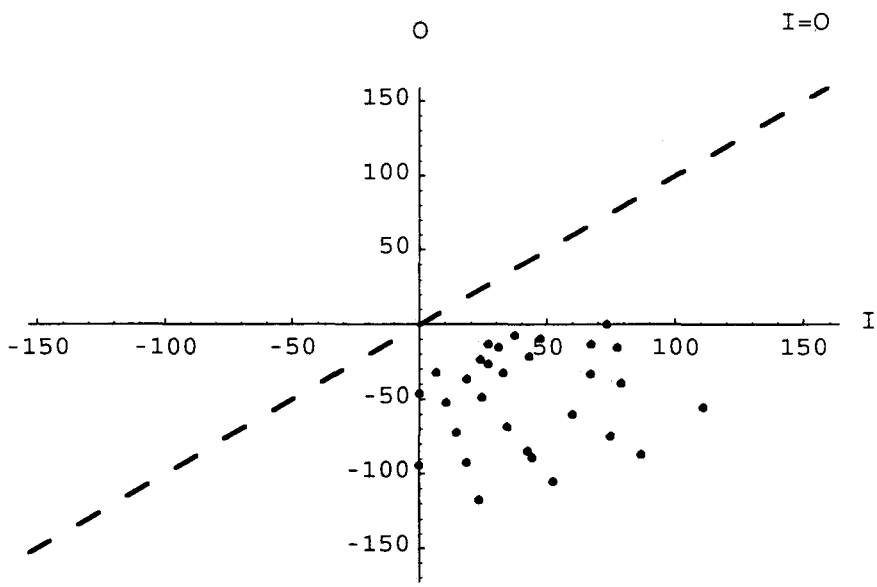
$$\left\{\frac{63}{4}, \frac{31}{4}, -\frac{25}{4}, \frac{11}{4}, -\frac{5}{4}, \frac{11}{4}, -\frac{37}{4}, -\frac{49}{4}\right\}$$

```
(*==================   Ap. 4.9. ====================
=====================            ====================
=====================       M    ====================
```

Matriz de pesos correspondiente a un vector de parámetros p

```
M[p_]:=Block[{a,n,i,j},
        n = Length[p];
        Read["Cero.m"];
        a = Cero[n,n];
        For[i=1,i<=n,i++,
        For[j=1,j<=n,j++,
        If[i==j,a[[i,j]]=0,
        a[[i,j]]= p[[i]]+p[[j]]]]];
        Return[a]]*)
(* Ejemplo *)
Read["M.m"];Read["P.m"];Read["WT.m"];
2*M[P[WT]]
Close["M.m"];Close["P.m"];Close["WT.m"];
Clear[M,WT,P];
{{0, 47, 19, 37, 29, 37, 13, 7},
 {47, 0, 3, 21, 13, 21, -3, -9},
 {19, 3, 0, -7, -15, -7, -31, -37},
 {37, 21, -7, 0, 3, 11, -13, -19},
 {29, 13, -15, 3, 0, 3, -21, -27},
 {37, 21, -7, 11, 3, 0, -13, -19},
 {13, -3, -31, -13, -21, -13, 0, -43},
 {7, -9, -37, -19, -27, -19, -43, 0}}
```

```
(*==================  Ap. 4.10. ==================
====================            ====================
====================            ====================

     Representación gráfica de los puntos
de energía de L correspondientes a la matriz de
         pesos transformada  *)

Read["Pinta.m"];Read["Oct.m"];Read["L.m"];Read["WT.m"];
Pinta[L,Oct,WT]
Close["Pinta.m"];Close["Oct.m"];Close["L.m"];
Close["WT.m"];Clear[Pinta,Oct,WT,L];
```



```
(*====================   Ap. 4.11. ====================
======================              ====================
======================      LP      ====================

     Algoritmo de aprendizaje parámetrico

Clear[LP]
LP[P_]:=Block[{l,i,j,k,n,w},
        n=Length[P[[1]]];
        Read["Cero.m"];
        w=Cero[n,0];
        l=Length[P];
        For[i=1,i<=l,i++,
         For[j=1,j<=n,j++,
          If[P[[i]][[j]]==1,
           w[[j]]=w[[j]]+1/2,
            If[P[[i]][[j]]==0,
             w[[j]]=w[[j]]-1/2,0]]]];
        Return[w]]*)

(* Ejemplo *)

Read["LP.m"];Read["L.m"];
LP[L]
Close["LP.m"];Close["L.m"];
 29  13    15   3    5   3    21     27
{--, --, -(--), -, -(-), -, -(--), -(--)}
 2   2     2    2    2   2    2      2
```

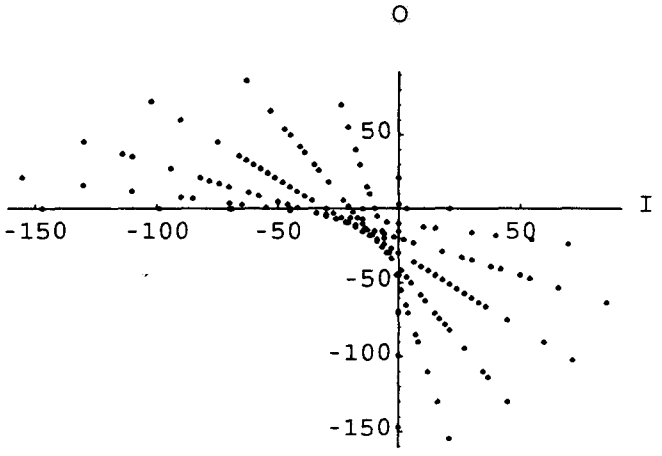
```
(*====================   Ap. 4.12. ====================
======================              ====================
======================      LP2     ====================

      Algoritmo de aprendizaje parámetrico
                (CENTRALIZADO)

Clear[LP2]
LP2[P_]:=Block[{l,i,j,k,n,w},
        n=Length[P[[1]]];
        Read["Cero.m"];
        w=Cero[n,0];
        l=Length[P];
        For[i=1,i<=l,i++,
         For[j=1,j<=n,j++,
          If[P[[i]][[j]]==1,
           w[[j]]=w[[j]]+1/2,
            If[P[[i]][[j]]==0,
             w[[j]]=w[[j]]-1/2,0]]]];
        m=Sum[w[[i]],{i,1,n}]/n;
        For[i=1,i<=n,i++,
        w[[i]]=w[[i]]-m];
        Return[w]]*)

(* Ejemplo *)
Read["LP2.m"];
Read["L.m"];
LP2[L]
Close["LP2.m"];
Close["L.m"];
```

$$\left\{\frac{63}{4}, \frac{31}{4}, -\frac{25}{4}, \frac{11}{4}, -\frac{5}{4}, \frac{11}{4}, -\frac{37}{4}, -\frac{49}{4}\right\}$$

```
(*==================   Ap. 4.13. ====================
=====================             ====================
=====================      ParPP  ====================

Clear[ParPP]
ParPP[v_,P_]:= Block[{r,s},
               Read["Sim.m"];
               Read["Cero.m"];
               r = Cero[2,0];
               s = Sim[v];
               r[[1]]=((v.v-1)P*v).v;
               r[[2]]=((s.s-1)P*s).s;
               Return [r];]*)
(* Ejemplo: *)
Clear["ParPP.m"];Read["ParPP.m"];Read["p"];
ParPP[{1,1,1,1,1,0,0,0},p]
Close["ParPP.m"];Close["p"];Clear[ParPP,p];
{50, -45}
(*===============      PriPP   ====================
Clear[PriPP]
PriPP[v_,P_]:= Block[{p},
               Read["ParPP.m"];
               p=ParPP[v,P][[1]];
               Return [p];]*)
(* Ejemplo: *)
Clear["PriPP.m"];
Read["PriPP.m"];Read["p"];Read["Oct2.m"];
PriPP[Oct2[[1]],p]
Close["PriPP.m"];Close["p"];Close["Oct2.m"];
Clear[PriPP,p,Oct2];
21
(*===============      SegPP   ====================
Clear[SegPP]
SegPP[v_,P_]:= Block[{s},
               Read["SegPP.m"];
               s=ParPP[v,P][[2]];
               Return [s];]*)
(* Ejemplo: *)
Clear["SegPP.m"];
Read["SegPP.m"];Read["p"];
SegPP[{1,1,1,1,1,0,0,0},p]
Close["SegPP.m"];Close["p"];
Clear[SegPP,p];
-45
(*===============     ParesPP  ====================
Clear[ParesPP]
ParesPP[L_,P_]:= Block[{p,n},
               Read["ParPP.m"];
               n = Length[L];
               p= Table[ParPP[L[[i]],P],{i,1,n}];
               Return [p]]*)
(* Ejemplo: *)
```

```
Clear["ParesPP.m"];Read["Oct2.m"];
Read["ParesPP.m"];Read["p"];
ParesPP[Oct2,p]
Close["ParesPP.m"];Close["p"];Close["Oct2.m"];
Clear[ParesPP,p,Oct2];
{{21, -155}, {7, -85}, {16, -130}, {12, -110},

 {16, -130}, {4, -70}, {1, -55}, {-1, -45}, {8, -90},

 {4, -70}, {8, -90}, {-4, -30}, {-7, -15}, {-6, -20},

 {-10, 0}, {-6, -20}, {-18, 40}, {-21, 55},

 {-1, -45}, {3, -65}, {-9, -5}, {-12, 10}, {-1, -45},

 {-13, 15}, {-16, 30}, {-9, -5}, {-12, 10}, {-24, 70}}
(*===============      ParposPP  ====================
Clear[ParposPP]
ParposPP[L_,A_]:= Block[{n,l,j,F},
                 Read["ParPP.m"];
                 Read["PriPP.m"];
                 n = Length[L];
                 j=0;
                 F=Table[PriPP[L[[i]],A],{i,1,n}];
                 For[i=1,i<=n,++i,
                 If[F[[i]]>=0,j=j+1,]];
                 Read["Cero.m"];
                 l=Cero[j,2];
                 j=1;
                 For[k=1,k<=n,++k,
                  If[PriPP[L[[k]],A]>=0,
                 l[[j]]=ParPP[L[[k]],A];j=j+1,]];
                Return [l]]*)
(* Ejemplo: *)
Read["ParposPP.m"];
Read["p"];Read["Oct2.m"];
ParposPP[Oct2,p]
Close["Oct2.m"];
Close["ParposPP.m"];
Close["p"];
Clear[p,Oct2,ParposPP];
{{21, -155}, {7, -85}, {16, -130}, {12, -110},

 {16, -130}, {4, -70}, {1, -55}, {8, -90}, {4, -70},

 {8, -90}, {3, -65}}
(*===============      PuntosPP  ====================
Clear[PuntosPP]
PuntosPP[X_,P_,n_]:= Block[{},
                 Read["ParesPP.m"];
                 ListPlot[ParesPP[X,P],
                 PlotStyle->{PointSize[n]},
                 FrameTicks->None,
                 AxesLabel->{"I","O"}]]*)
(* Ejemplo: *)
```

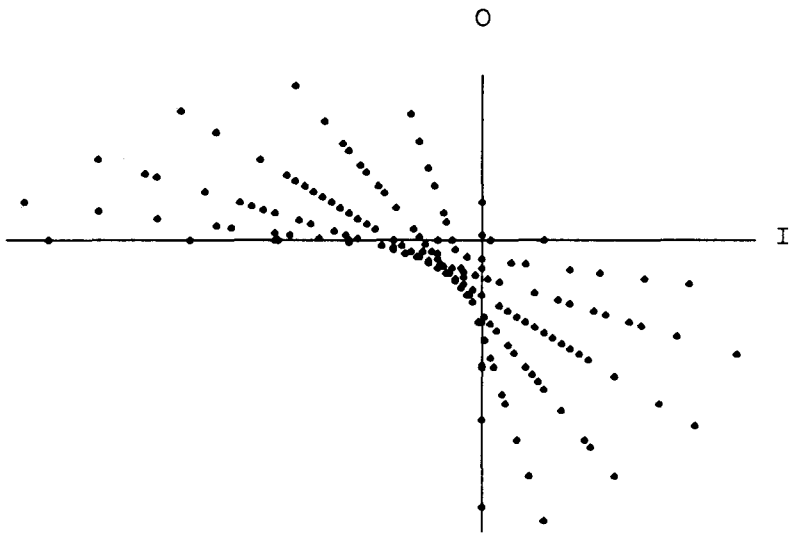
```
Read["p"];
Read["Oct.m"];
Read["PuntosPP.m"];
PuntosPP[Oct,p,0.006]
Close["p"];
Close["Oct.m"];
Close["PuntosPP.m"];
Clear[p,Oct,PuntosPP];
```



-Graphics-

```
(*================      Punto2PP     ====================
Clear[Punto2PP]
Punto2PP[X_,P_,n_]:= Block[{},
                  Read["ParesPP.m"];
                  ListPlot[ParesPP[X,P],
                  PlotStyle->{PointSize[n]},
                  FrameTicks->None,
                  Ticks->None,
                  AxesLabel->{"I","O"}]]*)
(* Ejemplo: *)
```

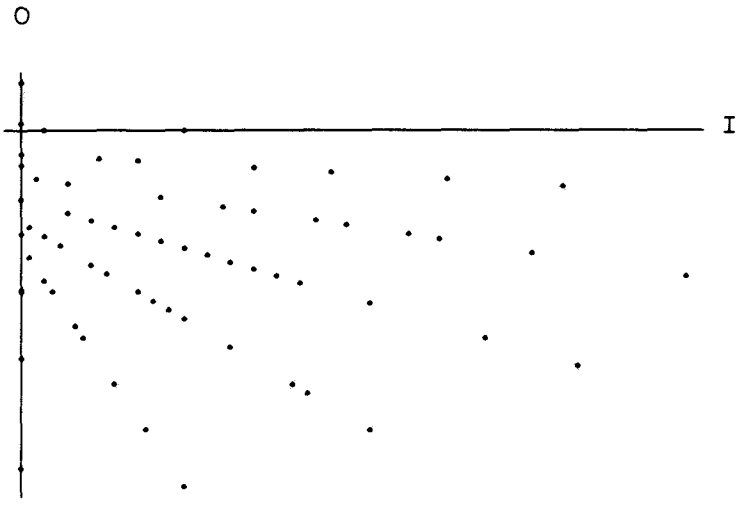
```
Read["p"];
Read["Oct.m"];
Read["Punto2PP.m"];
Punto2PP[Oct,p,0.006]
Close["p"];
Close["Oct.m"];
Close["Punto2PP.m"];
Clear[p,Oct,Punto2PP];
```



-Graphics-

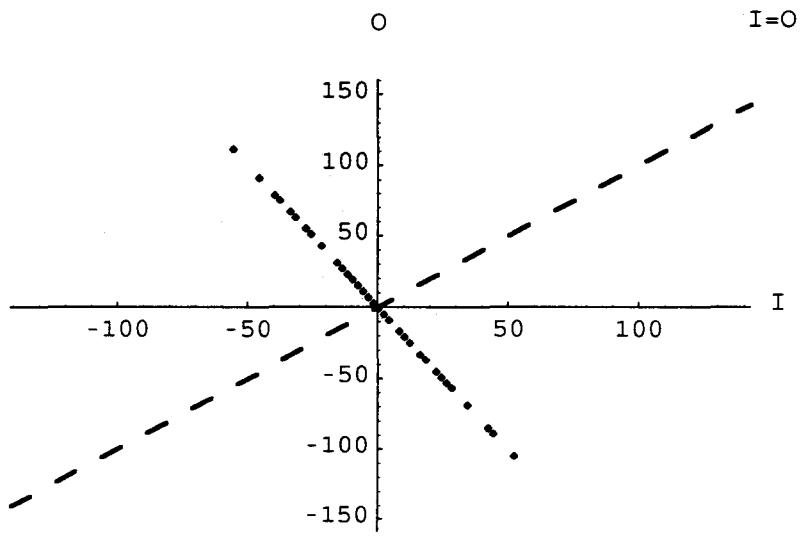
```
(*===============      Punto3PP     ====================
Clear[Punto3PP]
Punto3PP[X_,P_,n_]:= Block[{},
                Read["ParposPP.m"];
                ListPlot[ParposPP[X,P],
                PlotStyle->{PointSize[n]},
                FrameTicks->None,
                Ticks->None,
                AxesLabel->{"I","O"}]]*)
(* Ejemplo: *)
```

```
Clear[Punto3PP];
Read["p"];
Read["Oct.m"];
Read["Punto3PP.m"];
Punto3PP[Oct,p,0.006]
Close["p"];
Close["Oct.m"];
Close["Punto3PP.m"];
Clear[p,Oct,Punto3PP];
```




```
-Graphics-

(*================      PintaPP     ====================
Clear[PintaPP]
PintaPP[F_,T_,A_]:= Block[{},
        Read["PuntosPP.m"];
        Read["Listar.m"];
        Listar[F];
        Show[PuntosPP[F,A,.007],PuntosPP[T,A,.001],
        Graphics[{Dashing[{0.03,0.04}],
        Line[{{-300,-300},{300,300}}],
        Text["I=O",{150,200}]
        }],
        DisplayFunction:>$DisplayFunction]]*)
(* Ejemplo: *)
```

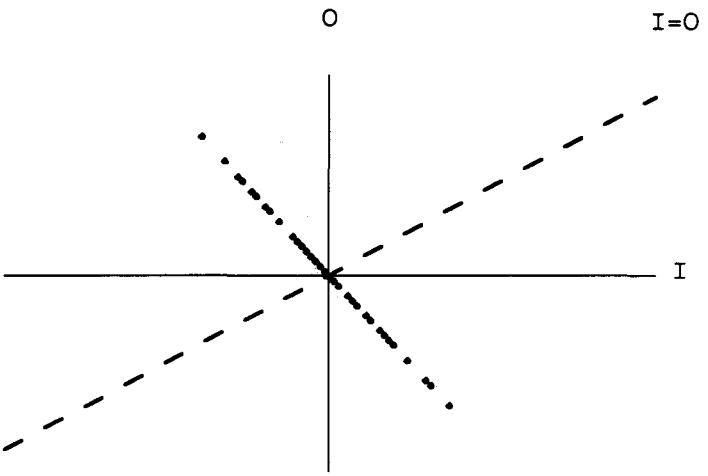
```
Clear[PintaPP];
Read["q"];Read["Oct.m"];Read["Oct3.m"];
Read["PintaPP.m"];
PintaPP[Oct3,Oct,q]
Close["q"];Close["Oct.m"];Close["Oct3.m"];
Close["PintaPP.m"];
Clear[q,Oct,Oct3,PintaPP];
```



-Graphics-

```
(*===============      Pinta2PP     ====================
Clear[Pinta2P]
Pinta2P[F_,T_,A_]:= Block[{},
        Read["Punto2PP.m"];
        Read["Listar.m"];
        Listar[F];
        Show[Punto2PP[F,A,.007],Punto2PP[T,A,.001],
        Graphics[{Dashing[{0.03,0.04}],
        Line[{{-300,-300},{300,300}}],
        Text["I=O",{150,200}]
        }],
        DisplayFunction:>$DisplayFunction]]*)
```

```
Clear[Pinta2P];
Read["q"];Read["Oct.m"];Read["Oct3.m"];
Read["Pinta2P.m"];
Pinta2P[Oct3,Oct,q]
Close["q"];Close["Oct.m"];Close["Oct3.m"];
Close["Pinta2P.m"];
Clear[q,Oct,Oct3,Pinta2P];
```



-Graphics-

```
(*================      ListPos     ====================
Clear[ListPos]
ListPos[G_,p_]:= Block[{m,n,j,k,l,A,F},
        Read["PriPP.m"];
        Read["ParPP.m"];
        F=Sort[G];
        n=Length[F];
        m=Length[F[[1]]];
        l=0;
        A={};
        j=1;
        k=1;
        While[k <= n,
        (Do[
        If[F[[i]]==F[[j]],k=k+1,],{i,j,n}];
        If[PriPP[F[[j]],p]>0,l=l+1;
        Print[F[[j]],N[ParPP[F[[j]],p]]],];
        j= k)];
        Read["Cero.m"];
        A=Cero[l,m];
        l=0;
        j=1;
        k=1;
        While[k <= n,
        (Do[
        If[F[[i]]==F[[j]],k=k+1,],{i,j,n}];
        If[PriPP[F[[j]],p]>0,
        l=l+1;
        A[[l]]=F[[j]],];
        j= k)];
        Return[A]]*)
```

```
(* Ejemplo: *)
Read["Oct2.m"];Read["q"];Read["ListPos.m"]
ListPos[Oct2,q];
Close["Oct2.m"];Close["q"];Close["ListPos.m"];
Clear[Oct2,ListPos,q];
```

```
{0, 0, 0, 0, 1, 1, 0, 0}{1.5, -7.5}
{0, 0, 0, 1, 0, 1, 0, 0}{5.5, -27.5}
{0, 0, 0, 1, 1, 0, 0, 0}{1.5, -7.5}
{0, 1, 0, 0, 0, 1, 0, 0}{10.5, -52.5}
{0, 1, 0, 0, 1, 0, 0, 0}{6.5, -32.5}
{0, 1, 0, 1, 0, 0, 0, 0}{10.5, -52.5}
{0, 1, 1, 0, 0, 0, 0, 0}{1.5, -7.5}
{1, 0, 0, 0, 0, 0, 0, 1}{3.5, -17.5}
{1, 0, 0, 0, 0, 0, 1, 0}{6.5, -32.5}
{1, 0, 0, 0, 0, 1, 0, 0}{18.5, -92.5}
{1, 0, 0, 0, 1, 0, 0, 0}{14.5, -72.5}
{1, 0, 0, 1, 0, 0, 0, 0}{18.5, -92.5}
{1, 0, 1, 0, 0, 0, 0, 0}{9.5, -47.5}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
```

```
(*===============      ListPos2     ====================
Clear[ListPos2]
ListPos2[G_,p_]:= Block[{m,n,j,k,l,A,B,F},
        Read["PriPP.m"];
        Read["ParPP.m"];
        F=Sort[G];
        n=Length[F];
        m=Length[F[[1]]];
        l=0;
        A={};
        j=1;
        k=1;
        While[k <= n,
        (Do[
        If[F[[i]]==F[[j]],k=k+1,],{i,j,n}];
        If[PriPP[F[[j]],p]>=0,l=l+1;
        If[ParPP[F[[j]],p]!={0,0},
        Print[F[[j]],N[ParPP[F[[j]],p]]],],];
        j= k)];
        Read["Cero.m"];
        A=Cero[l,m];
        l=1;
        j=1;
        k=1;
        B=1;
        While[k <= n,
        (Do[
        If[F[[i]]==F[[j]],k=k+1,],{i,j,n}];
        If[PriPP[F[[j]],p]>=0,
        If[ParPP[F[[j]],p]!={0,0},
        A[[l]]=F[[j]];l=l+1,],];
        j= k)];
        Return[A]]*)
(* Ejemplo: *)
```

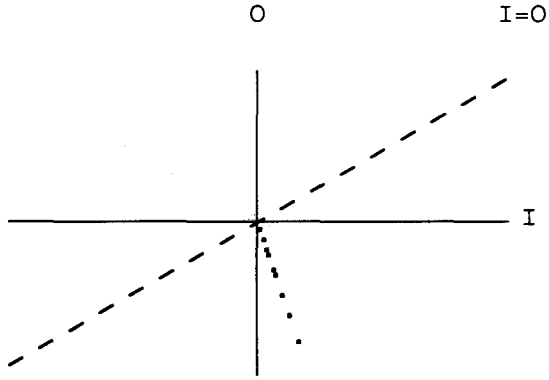
```
Read["Oct2.m"];Read["q"];Read["ListPos2.m"]
ListPos2[Oct2,q];
Close["Oct2.m"];Close["q"];Close["ListPos2.m"];
Clear[Oct2,ListPos2,q];
```

```
{0, 0, 0, 0, 1, 1, 0, 0}{1.5, -7.5}
{0, 0, 0, 1, 0, 1, 0, 0}{5.5, -27.5}
{0, 0, 0, 1, 1, 0, 0, 0}{1.5, -7.5}
{0, 1, 0, 0, 0, 1, 0, 0}{10.5, -52.5}
{0, 1, 0, 0, 1, 0, 0, 0}{6.5, -32.5}
{0, 1, 0, 1, 0, 0, 0, 0}{10.5, -52.5}
{0, 1, 1, 0, 0, 0, 0, 0}{1.5, -7.5}
{1, 0, 0, 0, 0, 0, 0, 1}{3.5, -17.5}
{1, 0, 0, 0, 0, 0, 1, 0}{6.5, -32.5}
{1, 0, 0, 0, 0, 1, 0, 0}{18.5, -92.5}
{1, 0, 0, 0, 1, 0, 0, 0}{14.5, -72.5}
{1, 0, 0, 1, 0, 0, 0, 0}{18.5, -92.5}
{1, 0, 1, 0, 0, 0, 0, 0}{9.5, -47.5}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
```

```
(*===============      Pinta3P     ===================
Clear[Pinta3P]
Pinta3P[F_,T_,A_]:= Block[{G},
        Read["Punto2PP.m"];
        Read["ListPos2.m"];
        G=ListPos2[F,A];
        Show[Punto2PP[G,A,.007],Punto2PP[T,A,.001],
        Graphics[{Dashing[{0.03,0.04}],
        Line[{{-300,-300},{300,300}}],
        Text["I=O",{150,200}]
        }],
        DisplayFunction:>$DisplayFunction]]*)
(* Ejemplo: *)
```

```
Read["q"];Read["Oct.m"];Read["Oct2.m"];
Read["Pinta3P.m"];Pinta3P[Oct2,Oct,q]
Close["q"];Close["Oct.m"];Close["Oct2.m"];
Close["Pinta3P.m"];
Clear[q,Oct,Oct2,Pinta3P];
```

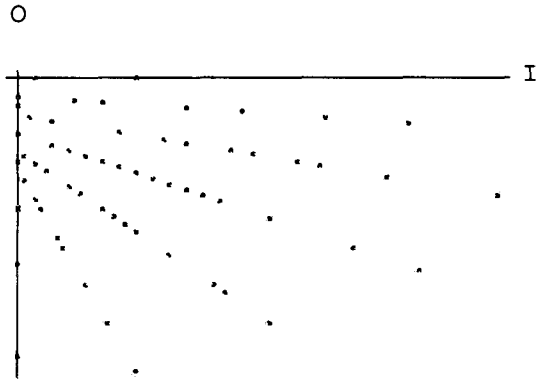
```
{0, 0, 0, 0, 1, 1, 0, 0}{1.5, -7.5}
{0, 0, 0, 1, 0, 1, 0, 0}{5.5, -27.5}
{0, 0, 0, 1, 1, 0, 0, 0}{1.5, -7.5}
{0, 1, 0, 0, 0, 1, 0, 0}{10.5, -52.5}
{0, 1, 0, 0, 1, 0, 0, 0}{6.5, -32.5}
{0, 1, 0, 1, 0, 0, 0, 0}{10.5, -52.5}
{0, 1, 1, 0, 0, 0, 0, 0}{1.5, -7.5}
{1, 0, 0, 0, 0, 0, 0, 1}{3.5, -17.5}
{1, 0, 0, 0, 0, 0, 1, 0}{6.5, -32.5}
{1, 0, 0, 0, 0, 1, 0, 0}{18.5, -92.5}
{1, 0, 0, 0, 1, 0, 0, 0}{14.5, -72.5}
{1, 0, 0, 1, 0, 0, 0, 0}{18.5, -92.5}
{1, 0, 1, 0, 0, 0, 0, 0}{9.5, -47.5}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
```



-Graphics-

```
Clear[ParrojPP]
ParrojPP[L_,A_]:= Block[{n,l,j},
                  n = Length[L];
                  j=1;
                  Read["Cero.m"];
                  l=Cero[n,2];
                  Close["Cero.m"];
                  Read["ParPP.m"];
                  For[k=1,k<=n,++k,
                   If[ParPP[L[[k]],A][[1]]>=0,
                     If[ParPP[L[[k]],A][[2]]<=0,
                       If[ParPP[L[[k]],A]!={0,0},
                     l[[j]]=ParPP[L[[k]],A];j=j+1,]]]];
                 l=Drop[l,{j,n}];

                  Close["ParPP.m"];
                 Return [l]]
Clear[ParrojPP]
ParrojPP[L_,A_]:= Block[{n,l,j},
                  n = Length[L];
                  j=1;
                  l=Table[0,{i,1,n},{k,1,2}];
                  Read["ParPP.m"];
                  For[k=1,k<=n,++k,
                   If[ParPP[L[[k]],A][[1]]>=0,
                     If[ParPP[L[[k]],A][[2]]<=0,
                       If[ParPP[L[[k]],A]!={0,0},
```

```
                    l[[j]]=ParPP[L[[k]],A];j=j+1,]]]];
                l=Drop[l,{j,n}];

                 Close["ParPP.m"];
                Return [l]]

Save["ParrojPP.m",ParrojPP]
Read["ParrojPP.m"];
Read["p"];Read["Oct2.m"];
ParrojPP[Oct2,p]
Close["Oct2.m"];
Close["ParrojPP.m"];
Close["p"];
Clear[p,Oct2,ParrojPP];
{{21, -155}, {7, -85}, {16, -130},

 {12, -110}, {16, -130}, {4, -70},

 {1, -55}, {8, -90}, {4, -70},

 {8, -90}, {3, -65}}
Clear[PunrojPP]
PunrojPP[X_,P_,n_]:= Block[{},
                Read["ParrojPP.m"];
                ListPlot[ParrojPP[X,P],
                PlotStyle->{PointSize[n],RGBColor[1,0,0]},
                FrameTicks->None,
                Ticks->None,
                AxesLabel->{"I","O"}]]

Save["PunrojPP.m",PunrojPP]
Clear[PunrojPP];
Read["p"];
Read["Oct.m"];
Read["PunrojPP.m"];
PunrojPP[Oct,p,0.006]
Close["p"];
Close["Oct.m"];
Close["PunrojPP.m"];
Clear[p,Oct,PunrojPP];
```

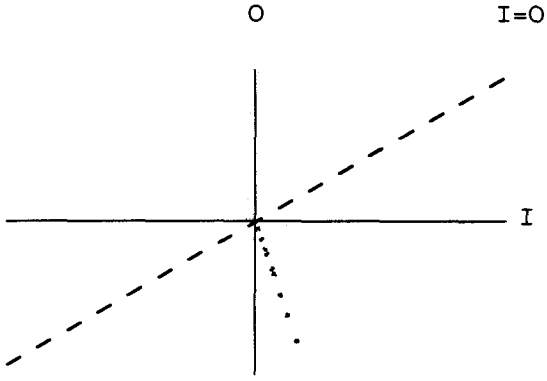



```
-Graphics-
Clear[Pintroj]
Pintroj[F_,T_,A_]:= Block[{G},
```

```
Read["Punto2PP.m"];
Read["PunrojPP.m"];
Read["ListPos2.m"];
G=ListPos2[F,A];
Show[PunrojPP[G,A,.007],Punto2PP[T,A,.001],
Graphics[{Dashing[{0.03,0.04}],
Line[{{-300,-300},{300,300}}],
Text["I=O",{150,200}]
}],
DisplayFunction:>$DisplayFunction]]
```

```
Save["Pintroj.m",Pintroj]
Read["q"];Read["Oct.m"];Read["Oct2.m"];
Read["Pintroj.m"];Pintroj[Oct2,Oct,q]
Close["q"];Close["Oct.m"];Close["Oct2.m"];
Close["Pintroj.m"];
Clear[q,Oct,Oct2,Pintroj];
```

```
{0, 0, 0, 0, 1, 1, 0, 0}{1.5, -7.5}
{0, 0, 0, 1, 0, 1, 0, 0}{5.5, -27.5}
{0, 0, 0, 1, 1, 0, 0, 0}{1.5, -7.5}
{0, 1, 0, 0, 0, 1, 0, 0}{10.5, -52.5}
{0, 1, 0, 0, 1, 0, 0, 0}{6.5, -32.5}
{0, 1, 0, 1, 0, 0, 0, 0}{10.5, -52.5}
{0, 1, 1, 0, 0, 0, 0, 0}{1.5, -7.5}
{1, 0, 0, 0, 0, 0, 0, 1}{3.5, -17.5}
{1, 0, 0, 0, 0, 0, 1, 0}{6.5, -32.5}
{1, 0, 0, 0, 0, 1, 0, 0}{18.5, -92.5}
{1, 0, 0, 0, 1, 0, 0, 0}{14.5, -72.5}
{1, 0, 0, 1, 0, 0, 0, 0}{18.5, -92.5}
{1, 0, 1, 0, 0, 0, 0, 0}{9.5, -47.5}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
```



```
(*====================   Ap. 5.1.  ====================
======================              ====================
======================     Eng      ====================

 La Energía asociada al vector x la definimos

Eng[x_, A_] := Block[{E, a, b},
                  Read["ParIO.m"];
                  a = ParIO[x, A][[1]];
                  b = ParIO[x, A][[2]];
                  E = b - a;
                  Return[E]]*)

(* Ejemplo: energía asociada al patrón (1,1,1,1,1,
0,0,0), respecto a la matriz transformada WT *)

Read["WT.m"];
Read["Eng.m"];
Eng[{1,1,1,1,1,0,0,0},WT]
Close["Eng.m"];
Close["WT.m"];
Clear[Eng];
Clear[WT];
```

$$\frac{225}{2}$$

```
(* Energía asociada al patrón (1,1,0,1,1,0,0,0),
respecto a la matriz transformada WT *)

Read["WT.m"];
Read["Eng.m"];
Eng[{1,1,0,1,1,0,0,0},WT]
Close["Eng.m"];
Close["WT.m"];
-150
```

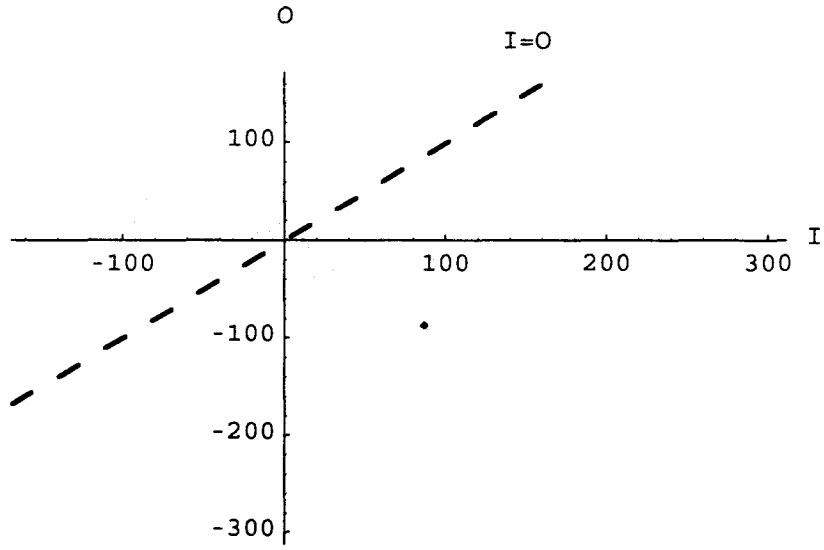
```
(*====================   Ap. 5.2. ====================
======================             ====================
======================    Hebb     ====================

     Algoritmo que nos dice si la componente
j-ésima del vector de estado x(t) debe pertenecer al
 subgrafo rojo o azul, dependiendo si su aportación
 al grafo rojo es mayor o menor que su aportación al
         azul. La matriz de pesos es A

Clear[Hebb]
Hebb[x_,A_,j_Integer]:=
        Block[{n,a,b,c,w,v},
        Read["Sim.m"];
        n = Length[x];
        a = x;
        b = x;
        a[[j]] = 1;
        b[[j]] = 0;
        w = A[[j]];
        If[a.w + Sim[b].w > 0,v=a,
         If[a.w + Sim[b].w < 0,v=b,v=x]];
        Return[v]]*)
(* Ejemplo: vemos que si el vector de estado es por
ejemplo el {1,1,1,1,1,0,0,0} y la matriz de pesos es
la matriz transformada WT, entonces el tercer vértice
da mayor aportación al grao azul que al rojo,
ya que *)

Read["WT.m"];
Read["Hebb.m"];
Hebb[{1,1,1,1,1,0,0,0},WT,3]
Close["Hebb.m"];
Close["WT.m"];
Clear[Hebb];
Clear[WT];
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
(*===============   IterHebb   ====================
   El siguiente algoritmo va preguntando de forma
asíncrona a todos los vértices del grafo si deben o no
 deben cambiar de color, es decir ejecuta Hebb1 desde
                 i=1 hasta i=n

Clear[IterHebb]
IterHebb[v_,A_] :=
        Block[{t,p,a,b},
                a=v;
                b=v;
                Read["Hebb.m"];
                Do[
                b = Hebb[a,A,i];
                a = b,{i,8}];
                Return[b]]*)
(* Aplicamos IterHebb al vector (1,1,1,1,1,0,0,0)
      repecto a la matriz transformada WT *)

Read["IterHebb.m"];
Read["WT.m"];
IterHebb[{1,1,1,1,1,0,0,0},WT]
Close["IterHebb.m"];
Close["WT.m"];
Clear[IterHebb];
Clear[WT];
{1, 1, 0, 1, 0, 1, 0, 0}
(*===============   RecHebb   ====================
   El siguiente algoritmo itera IterHebb hasta que el
      patrón de entrada coincide con el de salida.

Clear[RecHebb]
RecHebb[v_,A_] :=
        Block[{t,a,b,n},
                Read["IterHebb.m"];
                a = v;
                b = IterHebb[a,A];
                t=1;
                While[a!=b,
                  If[t==1,
                     b=IterHebb[a,A],
                     a=b;
                     b=IterHebb[a,A]];
                     t=t+1];
                Return[b]]*)
```

```
(* Ejemplo: *)

Read["WT.m"];
Read["RecHebb.m"];
RecHebb[{1,1,1,1,1,0,0,0},WT]
Close["WT.m"];
Close["RecHebb.m"];
Clear[WT];
Clear[RecHebb];
{1, 1, 0, 1, 0, 1, 0, 0}
```

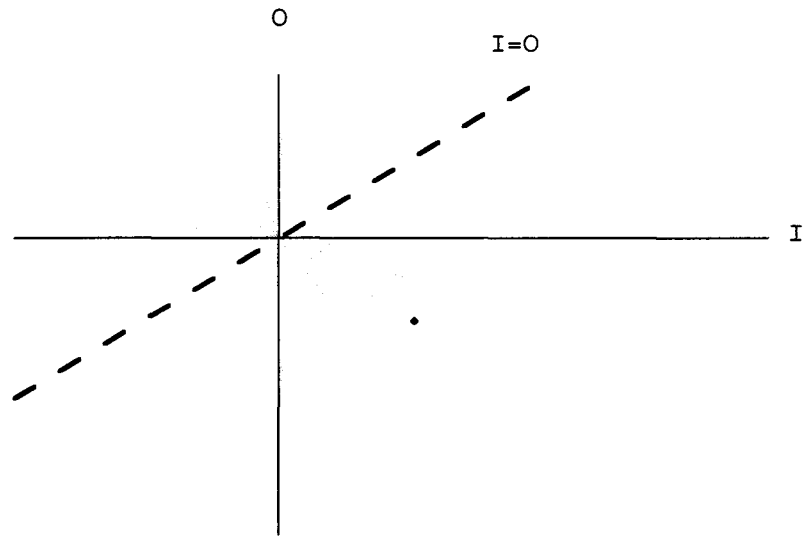
```
(*****************    Ap. 5.3.    **********************

Representamos gráficamente todos los PE´s corres-
pondientes a todos los posibles estados de la red
que son estables respecto al algoritmo RecHebb *)

Read["WT.m"];Read["Oct.m"];Read["RecHebb.m"];
Read["Pinta.m"];
F=Table[RecHebb[Oct[[i]],WT],{i,1,256}];
Pinta[F,Oct,WT]
Close["WT.m"];Close["Oct.m"];Close["RecHebb.m"];
Close["Pinta.m"];
Clear[WT,Oct,RecHebb,Pinta,F];
```

```
{1, 1, 0, 1, 0, 1, 0, 0}
```



```
(*Representamos gráficamente todos los PE´s corres-
pondientes a todos los posibles estados de la red
que son estables respecto al algoritmo RecHebb,
pero sin dibujar referencias *)

Read["WT.m"];Read["Oct.m"];Read["RecHebb.m"];
Read["Pinta2.m"];
F=Table[RecHebb[Oct[[i]],WT],{i,1,256}];
Pinta2[F,Oct,WT]
Close["WT.m"];Close["Oct.m"];Close["RecHebb.m"];
Close["Pinta2.m"];
Clear[WT,Oct,RecHebb,Pinta2,F];
```

```
{1, 1, 0, 1, 0, 1, 0, 0}
```



```
(*****************    Ap. 5.4.    ********************)

Solve[{x-y==It-Ot,x/(n1-2)+y/n0==0},{x,y}]
{{y -> -It + Ot +

     (-2 + n1) (-It + Ot)
--   --------------------,
         2 - n0 - n1

        (-2 + n1) (-It + Ot)
-- x -> --------------------}}
           2 - n0 - n1
```

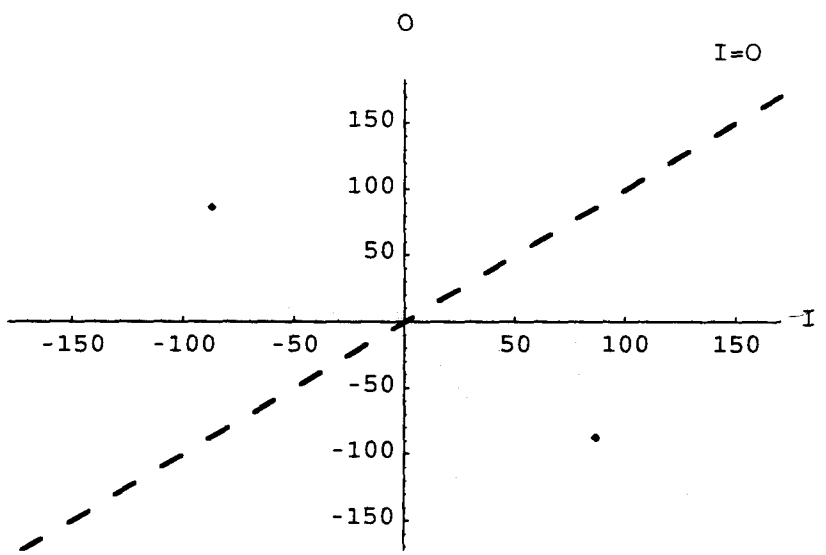
```
(*==================   Ap. 5.5. ====================
=====================           ====================
=====================    HebbP    ====================

Algoritmo que nos dice si la componente j-ésima del vector
de estado x(t) debe pertenecer al subgrafo rojo o azul,
dependiendo  su aportaciónal grafo rojo es mayor o menor
que su aportación al azul.El algoritmo HebbP tiene como
entrada el vector de estado x, el vector de parametros A
y la componente j respecto a la cual estamos viendo si su a
al subgrafo rojo es mayor o menor que su aportacion al
azul.

Clear[HebbP]
HebbP[x_,P_,j_Integer]:=
        Block[{n,n1,n0,a,b,v,q,WT},
        Read["Sim.m"];
        n = Length[x];
        n1 = x.x;
        n0 = n - n1;
        a = x;
        b = x;
        v = x;
        b[[j]] = 1;
        a[[j]] = 0;
        If[n0 == 1,q = P.Sim[b]/(n1-1)P.a,
        If[n1==1,q = P.Sim[b]/(n0-1)P.Sim[a],
        If[n0==0,v=a,If[n1==0,v=b,
        If[(n0-1)P.Sim[a]==(n1-1)P.a,v=x,
        q = P.Sim[b]/((n0-1)P.Sim[a]-(n1-1)P.a)]]]];
        If[q >1/(n-2),v=b,v=a];
        Return[v]]*)

(* Ejemplo: vemos que si el vector de estado es por
ejemplo el {1,1,1,1,1,0,0,0} y el vector de paramtros
es ele vector centralizado q, entonces el tercer
vértice dá mayor aportación al grafo azul que al rojo,
ya que *)

Read["q"];
Read["HebbP.m"];
HebbP[{1,1,1,1,1,0,0,0},q,3]
Close["HebbP.m"];
Close["q"];
Clear[HebbP];
Clear[q];
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
(*===============      IterHebP    ====================

El algoritmo IterHebP itera el algoritmo HebbP de la
primera a la ultima componente; es decir, va preguntando
a todas y cada una de las neuronas de pla primera a la
última si dicha neuona debe pertenecer al grafo rojo o al
azul

Clear[IterHebP]
IterHebP[v_,A_] :=
        Block[{t,p,a,b},
                a=v;
                b=v;
                Read["HebbP.m"];
                Do[
                b = HebbP[a,A,i];
                a = b,{i,8}];
                Return[b]]*)
(* Aplicamos IterHebP al vector (1,1,1,1,1,0,0,0) *)

Read["IterHebP.m"];
Read["q"];
IterHebP[{1,1,1,1,1,0,0,0},q]
Close["IterHebP.m"];
Close["q"];
Clear[IterHebP];
Clear[q];
{1, 1, 0, 1, 0, 1, 0, 0}
```

```
(*===============      RecHebP    ====================

  El siguiente módulo itera IterHeb1 hasta que la
        entrada es igual a la salida

Clear[RecHebP]
RecHebP[v_,A_] :=
        Block[{t,a,b,n},
                Read["IterHebP.m"];
                a = v;
                n = Length[v];
                b=IterHebP[a,A];
                t=1;
                While[a!=b,
                  If[t==1,
                     b=IterHebP[a,A],
                     a=b;
                     b=IterHebP[a,A]];
                     t=t+1];
                Return[b]]*)

(* Aplicamos RecHebP al vector (1,1,1,1,1,0,0,0) *)

Read["q"];
Read["RecHebP.m"];
RecHebP[{1,1,1,1,1,0,0,0},q]
Close["q"];
Close["RecHebP.m"];
Clear[q];
Clear[RecHebP];
{1, 1, 0, 1, 0, 1, 0, 0}
```

```
(*====================   Ap. 5.6. ====================
======================              ====================
======================              ====================

  Ejemplo, podemos representar gráficamente todos
 los PE´s correspondientes a los puntos de salida
de aplicar el algoritmo RecHebP a todos los posibles
              estados de la red                        *)

Read["q"];Read["Oct.m"];Read["RecHebP.m"];
Read["PintaPP.m"];
F=Table[RecHebP[Oct[[i]],q],{i,1,25}];
PintaPP[F,Oct,q]
Close["q"];Close["Oct.m"];Close["RecHebP.m"];
Close["PintaPP.m"];
Clear[q,Oct,RecHebP,PintaPP,F];
```

```
{0, 0, 1, 0, 1, 0, 1, 1}
{1, 1, 0, 1, 0, 1, 0, 0}
```



-Graphics-

```
(*====================   Ap. 5.7.  ====================
======================              ====================
======================     RejIO    ====================

 ReljIO[x_,A,j], es la función con la cual se obtiene el
 peso relativo del vértice j-esimo del vector x respecto
                    a la matriz A.

Clear[ReljIO]
ReljIO[x_,A_,j_Integer]:=
        Block[{w,PriIO,SegIO,Relj,s},
        Read["Sim.m"];
        s = Sim[x];
        Read["ParIO.m"];
        PriIO = ParIO[x,A][[1]];
        SegIO = ParIO[x,A][[2]];
        w ={};
        w = A[[j]];
        If[x[[j]]==1,
         If[PriIO == 0,Relj=2/x.x,Relj=x.w/PriIO],
           If[SegIO == 0,Relj=2/s.s,Relj=s.w/SegIO]];
        Return[Relj]]*)
(* Ejemplo: *)
Read["W.m"];Read["ReljIO.m"];
ReljIO[{1,1,1,1,1,0,0,0},W,3]
Close["W.m"];Close["ReljIO.m"];
Clear[W,ReljIO];
```

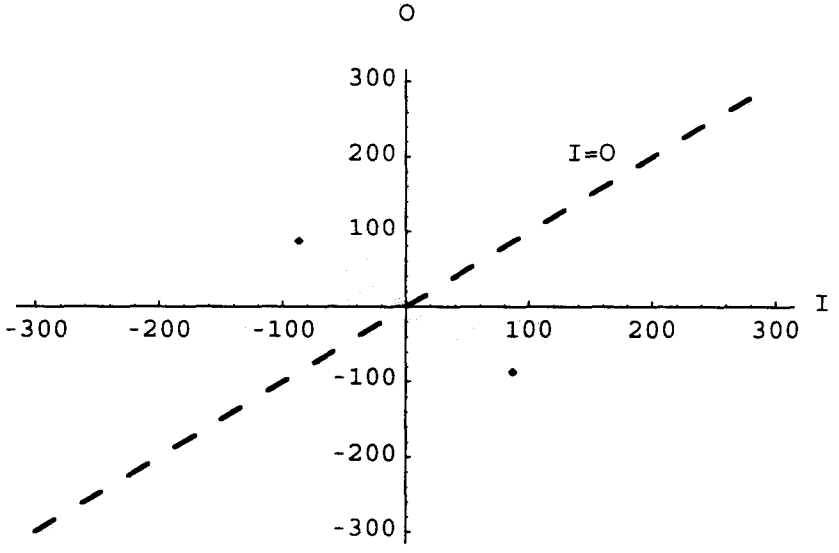
$$-\left(-\frac{1}{5}\right)$$

```
(*====================   Ap. 5.8. ====================
======================              ====================
======================    Hebb1     ====================

Clear[Hebb1]
Hebb1[x_,A_,j_Integer]:= Block[{n,Relj,Ra,Rb,v,a,b,c},
        Read["ReljIO.m"];
        v = x;
        a = x;
        b = x;
        a[[j]] = 1;
        b[[j]] = 0;
        n = Length[x];
        Read["Sim.m"];
        c = Sim[b];
        Ra = ReljIO[a,A,j];
        Rb = ReljIO[c,A,j];
        If[Ra > Rb,v=a,If[Rb > Ra,v=b,v=x]];
        Return[v]]*)
(* Ejemplo: *)

Read["WT.m"];Read["Hebb1.m"];
Hebb1[{1,1,1,1,1,0,0,0},WT,3]
Close["WT.m"];Close["Hebb1.m"];
Clear[Hebb1];
{1, 1, 0, 1, 1, 0, 0, 0}
(*===============     IterHeb1   ====================
Clear[IterHeb1]
IterHeb1[v_,A_] :=
        Block[{t,p,a,b},
                Read["Hebb1.m"];
                a=v;b=v;
                Do[
                b = Hebb1[a,A,i];
                a = b,{i,8}];
                Return[b]]*)
(* Ejemplo: *)

Read["WT.m"];Read["IterHeb1.m"];
IterHeb1[{1,1,1,1,1,0,0,0},WT]
Close["WT.m"];Close["IterHeb1.m"];
Clear[WT,IterHeb1];
{1, 1, 0, 1, 1, 1, 0, 0}
```

```
(*===============      RecHeb1    ====================
Clear[RecHeb1]
RecHeb1[v_,A_] :=
        Block[{t,a,b,n},
                Read["IterHeb1.m"];
                a = v;
                n = Length[v];
                b=IterHeb1[a,A];
                t=1;
                While[a!=b,
                  If[t==1,
                     b=IterHeb1[a,A],
                     a=b;
                     b=IterHeb1[a,A]];
                     t=t+1];
                Return[b]]*)
(* Ejemplo: *)

Read["WT.m"];Read["RecHeb1.m"];
RecHeb1[{1,1,1,1,1,0,0,0},WT]
Close["WT.m"];Close["RecHeb1.m"];
Clear[WT,RecHeb1];
{1, 1, 0, 1, 0, 1, 0, 0}
```

```
(*====================   Ap. 5.9.  ====================
=====================              ====================
=====================              ====================

  Ejemplo, podemos representar gráficamente todos
  los PE´s correspondientes a los puntos de salida
de aplicar el algoritmo RecHebP a todos los posibles
           estados de la red                          *)

Read["WT.m"];Read["Oct.m"];Read["RecHeb1.m"];
Read["Pinta.m"];
F=Table[RecHeb1[Oct[[i]],WT],{i,1,256}];
Pinta[F,Oct,WT]
Close["WT.m"];Close["Oct.m"];Close["RecHeb1.m"];
Close["Pinta.m"];
Clear[WT,Oct,Pinta,F,RecHeb1];
```

```
{0, 0, 1, 0, 1, 0, 1, 1}
{1, 1, 0, 1, 0, 1, 0, 0}
```



```
(*==================   Ap. 5.10. ====================
====================            ====================
====================    RejPP   ====================

Peso relativo del vértice j-esimo, la entrada es
el vector de estado x, el vector de parámetros p
      y la componente j-esima

Clear[RejPP]
RejPP[x_,P_,j_Integer]:= Block[{w,n,s},
        Read["Sim.m"];
        s = Sim[x];
        n = Length[x];
        w = 0;
        If[x[[j]] == 1,
         If[x.x == n,w=4/n,
          If[x.x == 1,w=2,
           If[P.x == 0,w = 2/x.x,
            w=1/(x.x-1)+((x.x-2)*P[[j]])/((x.x-1)*P.x)]]],
        If[s.s == n,w=4/n,
         If[s.s == 1,w=2,
          If[P.s == 0, w = 2/s.s,
         w = 1/(s.s-1)+((s.s-2)*P[[j]])/((s.s-1)*P.s)]]]];
        Return[w]]*)
(* Ejemplo *)

Read["p"];Read["RejPP.m"];
RejPP[{1,1,1,1,1,0,0,0},p,5]
Close["p"];Close["RejPP.m"];
Clear[p,RejPP];
```

$$\frac{1}{10}$$

In[1]:=

```
(*===============      VecprPP    ====================

Vector de pesos relativos: la entrada es el vector
de estado x y el vector de parámetros p. La salida
es el vector cuyas componentes son los pesos relati-
vos de cada uno de los vértices


Clear[VecprPP]
VecprPP[x_,p_] := Block[{w,j},
        n = Length[x];
        Read["ReljPP.m"];
        w = Table[ReljPP[x,p,j],{j,1,n}];
        Return[w]]*)

(*Ejemplo *)

Read["p"];Read["VecprPP.m"];
VecprPP[{1,1,1,1,1,0,0,0},p]
Close["p"];Close["VecprPP.m"];
Clear[p,VecprPP];
```

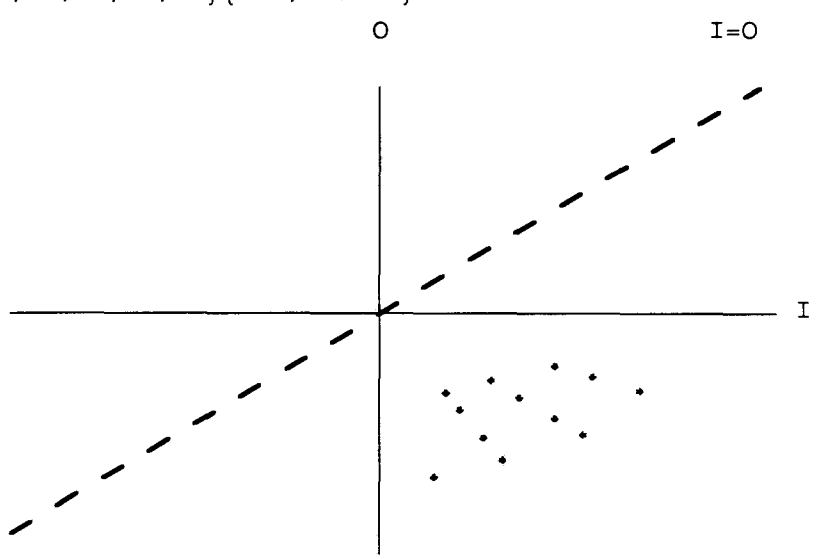
```
 28  16    1   17  1   7   11  4
{--, --, -(-), --, --, --, --, -}
 25  25    5   50  10  15  15  5
```

```
(*====================   Ap. 5.11. ====================
======================              ====================
======================    Heb2P     ====================
Clear[Heb2P]
Heb2P[x_,A_,j_Integer]:= Block[{n,Relj,v,a,b},
        Read["ReljPP.m"];
        v = x;
        a = x;
        b = x;
        a[[j]] = 1;
        b[[j]] = 0;
        n = Length[x];
        Relj = ReljPP[x,A,j];
If[v[[j]]==1,If[Relj > 0,v=a,If[Relj < 0,v=b,v=x]],
If[Relj > 0,v=b,If[Relj < 0,v=a,v=x]]];

        Return[v]]*)
(* Ejemplo *)

Read["p"];Read["Heb2P.m"];
Heb2P[{1,1,1,1,1,0,0,0},p,3]
Close["p"];Close["Heb2P.m"];
Clear[p,Heb2P];
{1, 1, 0, 1, 1, 0, 0, 0}
(*===============      ItrHeb2P  ====================
Clear[ItrHeb2P]
ItrHeb2P[v_,A_] :=
        Block[{t,p,a,b},
                Read["Heb2P.m"];
                a=v;b=v;
                Do[
                b = Heb2P[a,A,i];
                a = b,{i,8}];

                Return[b];]*)
(* Ejemplo *)

Read["p"];Read["ItrHeb2P.m"];
ItrHeb2P[{1,1,1,1,1,0,0,0},p]
Close["p"];Close["ItrHeb2P.m"];
Clear[p,ItrHeb2P];
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
(*===============      RcHeb2P  ====================
Clear[RcHeb2P]
RcHeb2P[v_,A_] :=
        Block[{t,a,b,n},
                Read["ItrHeb2P.m"];
                Read["Cero.m"];
                Read["Uno.m"];
                a = v;
                n = Length[v];
                If [a==Cero[n,0],b=Uno[n,0],b=Cero[n,0]];
                t=1;
                While[a!=b,
                  If[t==1,
                     b=ItrHeb2P[a,A],
                     a=b;
                     b=ItrHeb2P[a,A]];
                     t=t+1];
                Return[b]]*)
(* Ejemplo *)

Read["p"];Read["RcHeb2P.m"];
RcHeb2P[{1,1,1,1,1,0,0,0},p]
Close["p"];Close["RcHeb2P.m"];
Clear[p,RcHeb2P];
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
(*Ejemplo, podemos representar gráficamente todos
 los PE´s correspondientes a los puntos de salida
de aplicar el algoritmo RecHebP a todos los posibles
          estados de la red *)
Read["q"];Read["Oct.m"];Read["RcHeb2P.m"];
F=Table[RcHeb2P[Oct[[i]],q],{i,1,256}];
Close["RcHeb2P.m"];
Clear[RcHeb2P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
```

```
{1, 0, 0, 1, 1, 1, 0, 0}{60., -60.}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
{1, 1, 0, 0, 0, 0, 1, 0}{28.5, -57.}
{1, 1, 0, 0, 0, 1, 0, 0}{52.5, -105.}
{1, 1, 0, 0, 1, 0, 0, 0}{44.5, -89.}
{1, 1, 0, 0, 1, 1, 0, 0}{75., -75.}
{1, 1, 0, 1, 0, 0, 0, 0}{52.5, -105.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 1, 0, 0, 0}{75., -75.}
{1, 1, 0, 1, 1, 1, 0, 0}{111., -55.5}
{1, 1, 1, 0, 0, 0, 0, 0}{34.5, -69.}
{1, 1, 1, 0, 0, 1, 0, 0}{60., -60.}
{1, 1, 1, 0, 1, 0, 0, 0}{48., -48.}
{1, 1, 1, 0, 1, 1, 0, 0}{75., -37.5}
{1, 1, 1, 1, 0, 0, 0, 0}{60., -60.}
{1, 1, 1, 1, 0, 1, 0, 0}{91., -45.5}
{1, 1, 1, 1, 1, 0, 0, 0}{75., -37.5}
```



-Graphics-

```
(*====================    Ap. 6.1.  ====================
======================              ======================
======================              ==================*)

Read["q"];Read["ReljPP.m"];
N[ReljPP[{1,1,1,1,1,1,0,0},q,4]]
Close["q"];Close["ReljPP.m"];
Clear[q,ReljPP];

0.302326
```

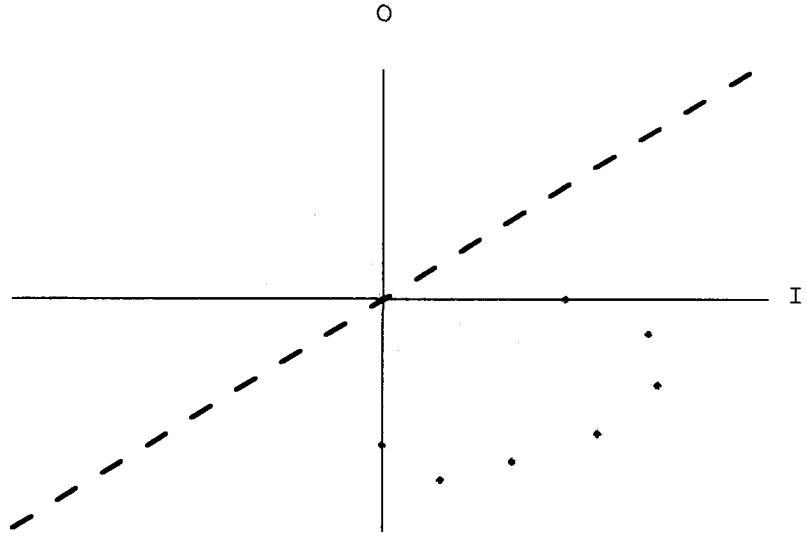
```
(*====================   Ap. 6.2.  ====================
======================              ====================
======================   ProAbs     ====================

Algoritmo que teniendo como entrad un vector de
parámetros q, nos da como salida los prototipos
absolutos

Clear[ProAbs]
ProAbs[p_,j_Integer]:= Block[{q,m,s,n,f},
        Read["Cero.m"];
        n=Length[p];
        s=Cero[n,n];
        Close["Cero.m"];
        Clear[Cero];
        f=0;
        q=Reverse[Sort[p]];
        For[i=1,i<=n,++i,f=0;
        m=q[[i]];If[i==1,,s[[i]]=s[[i-1]]];
        For[k=1,k<=n ,++k,
        If[p[[k]]==m ,
        If[s[[i,k]]==0,If[f==0,s[[i,k]]=1;f=1,],]]]];
        Return[s[[j]]]]*)

(* Ejemplo: *)
Read["q"];Read["ProAbs.m"];
Table[ProAbs[q,i],{i,1,Length[q]}]
Close["q"];Close["ProAbs.m"];
Clear[q,ProAbs]
{{1, 0, 0, 0, 0, 0, 0, 0},

 {1, 1, 0, 0, 0, 0, 0, 0},

 {1, 1, 0, 1, 0, 0, 0, 0},

 {1, 1, 0, 1, 0, 1, 0, 0},

 {1, 1, 0, 1, 1, 1, 0, 0},

 {1, 1, 1, 1, 1, 1, 0, 0},

 {1, 1, 1, 1, 1, 1, 1, 0},

 {1, 1, 1, 1, 1, 1, 1, 1}}
```

```
(* Listamos los PE`s de los Prototipos Absolutos *)

Read["q"];Read["ProAbs.m"];
Read["ParesPP.m"];
P=Table[ProAbs[q,i],{i,1,Length[q]}];
Do[Print[ParesPP[P,q][[j]]],{j,1,8}]
Close["q"];Close["ProAbs.m"];Close["ParesPP.m"];
Clear[q,ProAbs,ParesPP,P]
```

```
      189
{0, -(---)}
       2
 47    235
{--, -(---)}
 2      2
 105
{---, -105}
  2
{87, -87}
        111
{111, -(---)}
         2
 215    43
{---, -(--)}
  2     2
 147
{---, 0}
  2
{0, 0}
```

```
(*====================    Ap. 6.3. ====================
=====================              =====================
=====================              ==================*)
Read["q"];Read["ProAbs.m"];Read["Pintar2P.m"];
Read["Oct.m"];
F=Table[ProAbs[q,i],{i,1,Length[q]}];
Pintar2P[F,Oct,q]
Close["q"];Close["ProAbs.m"];
Close["Pintar2P.m"];Close["Oct.m"];
Clear[q,ProAbs,Pintar2P,F,Oct]
```

```
{1, 0, 0, 0, 0, 0, 0, 0}
{1, 1, 0, 0, 0, 0, 0, 0}
{1, 1, 0, 1, 0, 0, 0, 0}
{1, 1, 0, 1, 0, 1, 0, 0}
{1, 1, 0, 1, 1, 1, 0, 0}
{1, 1, 1, 1, 1, 1, 0, 0}
{1, 1, 1, 1, 1, 1, 1, 0}
{1, 1, 1, 1, 1, 1, 1, 1}
```



```
(*====================   Ap. 6.4. ====================
=====================             ====================
=====================             ==================*)
Read["q"];Read["ProAbs.m"];
Read["VecprPP.m"];
F=Table[ProAbs[q,i],{i,1,Length[q]}];
Table[VecprPP[F[[i]],q],{i,1,Length[q]}]
Close["q"];Close["ProAbs.m"];Close["VecprPP.m"];
Clear[q,ProAbs,VecprPP,F]
```

```
       46    94    4   44    4   124
{{{0, -(---), ---, ---, ---, ---, ---,
       189   189  189  189  189  189

  22          97   5   57   5   121
-- --}, {0, 0, ---, --, ---, --, ---,
  27          235  47  235  47  235

  29    4  68   3  58   2  6   18  3
-- --}, {-, ---, -, ---, -, --, --, -},
  47    5  105  7  105  7  35  35  5

  121  89   83   23  21  23  95
-{---, ---, ---, --, --, --, ---,
  174  174  174  58  58  58  174

  107    25  17  68   12  8   12  2
-- ---}, {--, --, ---, --, --, --, -,
  174    37  37  111  37  37  37  3

  80     169  21     7    13  33   13
-- ---}, {---, --, -(---), --, ---, --,
  111    215  43    215   43  215  43

          26  34    38    52   4
-- 0, 0}, {--, --, -(---), ---, --,
          21  49    147   147  49

  52     68
-- ---, -(---), 0},
  147    147

 {0, 0, 0, 0, 0, 0, 0, 0}}
```

```
(*==================   Ap. 6.5. ====================
====================             ====================
====================             ==================*)

Read["q"];Read["ProAbs.m"];Read["VecprPP.m"];
F=Table[ProAbs[q,i],{i,1,Length[q]}];
Table[Min[VecprPP[F[[i]],q]],{i,1,Length[q]}]
Close["q"];Close["ProAbs.m"];Close["VecprPP.m"];
Clear[L,q,ProAbs,VecprPP]
```

$$\left\{\frac{46}{189}, 0, \frac{6}{35}, \frac{21}{58}, \frac{8}{37}, -\frac{7}{215}, \frac{68}{147}, 0\right\}$$

```
(*====================    Ap. 6.6.  ====================
======================              ====================
======================              ==================*)

Read["q"];Read["ProAbs.m"];Read["VecprPP.m"];
F=Table[ProAbs[q,i],{i,1,Length[q]}];
b=Max[Table[Min[VecprPP[F[[i]],q]],{i,1,Length[q]}]]
Close["q"];Close["ProAbs.m"];Close["VecprPP.m"];
Clear[L,q,ProAbs,VecprPP]
21
--
58
(*====================  Umb    ====================

Umb[p_]:= Block[{n0,n1,n,a1,a2,a,b1,b2,b,u},
        Read["Sim.m"];
        Read["Cero.m"];
        n = Length[p];
        u = Cero[n,0];
        For[i=1,i<=n,i++,
        u[[i]] =1];
        For[j=3,j<=n-2,j++,
        a = N[1-Sqrt[((n-j-1)(j-2))/((j-1)(n-j))]];
        u[[j]] =a];
        Return[u]]*)

Read["q"];Read["Umb.m"];
L=Umb[q]
a = Min[L]
Min[a,b]
Close["q"];Close["Umb.m"];
Clear[a,b,q,Umb,L];
{1, 1, 0.367544, 0.292893, 0.292893,

 0.367544, 1, 1}
0.292893
0.292893
```

```
(*====================   Ap. 6.7. ====================
======================             ====================
======================   Heb3P    ====================

Clear[Heb3P]
Heb3P[x_,A_,p_,j_Integer]:= Block[{n,Relj,v,a,b},
        Read["ReljPP.m"];
        v = x;
        a = x;
        b = x;
        a[[j]] = 1;
        b[[j]] = 0;
        n = Length[x];
        Relj = ReljPP[x,A,j];
If[v[[j]]==1,If[Relj > p,v=a,If[Relj < p,v=b,v=x]],
If[Relj > p,v=b,If[Relj < p,v=a,v=x]]];

        Return[v]]*)


Read["p"];Read["ReljPP.m"];
ReljPP[{1,1,1,1,1,0,0,0},p,3]
Close["p"];Close["ReljPP.m"];
Clear[p,ReljPP];
```

$$-\left(-\frac{1}{5}\right)$$

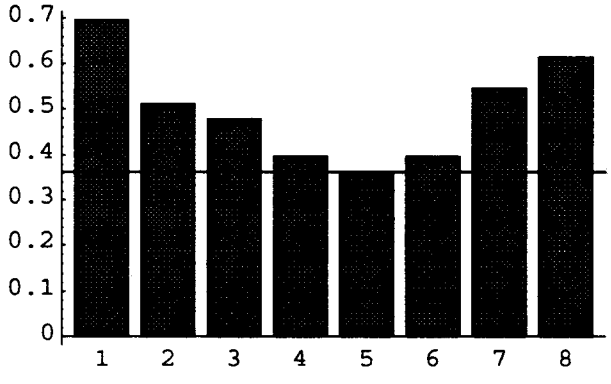
```
Read["p"];Read["Heb3P.m"];
Heb3P[{1,1,1,1,1,0,0,0},p,0.292893,3]
Close["p"];Close["Heb3P.m"];
Clear[p,Heb3P];
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
(*====================   Ap. 6.8. ====================
=====================              ====================
=====================   ItrHeb3P ====================

Clear[ItrHeb3P]
ItrHeb3P[v_,A_,p_] := Block[{a,b},
                Read["Heb3P.m"];
                a=v;
                b=v;
                n = Length[v];
                Do[
                b = Heb3P[a,A,p,i];
                a = b,{i,n}];
                Return[b]]*)

(*====================   Ap. 6.9. ====================
=====================              ====================
=====================              ==================*)

Read["p"];Read["ItrHeb3P.m"];
ItrHeb3P[{1,1,1,1,1,0,0,0},p,0.292893]
Close["p"];Close["ItrHeb3P.m"];
Clear[p,ItrHeb3P];
{1, 1, 0, 1, 0, 1, 0, 0}

(*====================   Ap. 6.10. ====================
=====================              ====================
=====================    EngPP     ====================

Clear[EngPP]
EngPP[x_,p_]:= Block[{e,a,b},
                Read["PriPP.m"];
                Read["SegPP.m"];
                a = PriPP[x,p];
                b = SegPP[x,p];
                e = a*b;
                Return[e]]*)
```

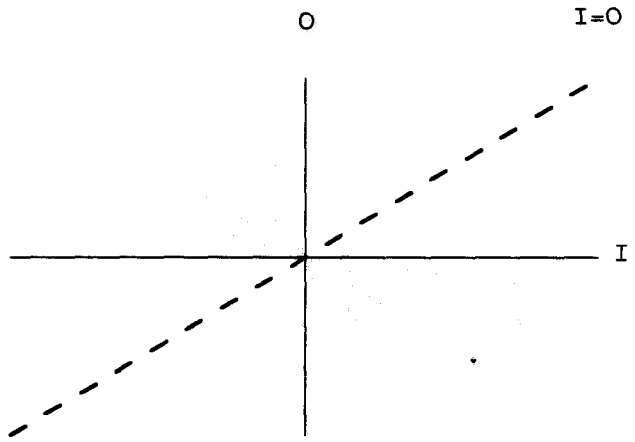
```
(*====================    Ap. 6.11.  ====================
====================                ====================
====================                ==================*)

Read["p"];Read["Heb3P.m"];Read["Heb3P.m"];
Read["EngPP.m"];
{{1,1,1,1,1,0,0,0},EngPP[{1,1,1,1,1,0,0,0},p]}
{Heb3P[{1,1,1,1,1,0,0,0},p,21/58,1],
EngPP[Heb3P[{1,1,1,1,1,0,0,0},p,21/58,1],p]}
{Heb3P[{1,1,1,1,1,0,0,0},p,21/58,2],
EngPP[Heb3P[{1,1,1,1,1,0,0,0},p,21/58,2],p]}
{Heb3P[{1,1,1,1,1,0,0,0},p,21/58,3],
EngPP[Heb3P[{1,1,1,1,1,0,0,0},p,21/58,3],p]}
{Heb3P[{1,1,0,1,1,0,0,0},p,21/58,4],
EngPP[Heb3P[{1,1,0,1,1,0,0,0},p,21/58,4],p]}
{Heb3P[{1,1,0,1,1,0,0,0},p,21/58,5],
EngPP[Heb3P[{1,1,0,1,1,0,0,0},p,21/58,5],p]}
{Heb3P[{1,1,0,1,0,0,0,0},p,21/58,6],
EngPP[Heb3P[{1,1,0,1,0,0,0,0},p,21/58,6],p]}
{Heb3P[{1,1,0,1,0,1,0,0},p,21/58,7],
EngPP[Heb3P[{1,1,0,1,0,1,0,0},p,21/58,7],p]}
{Heb3P[{1,1,0,1,0,1,0,0},p,21/58,8],
EngPP[Heb3P[{1,1,0,1,0,1,0,0},p,21/58,8],p]}

Close["p"];Close["Heb3P.m"];Close["EngPP.m"];
Clear[p,Heb3P,EngPP];
{{1, 1, 1, 1, 1, 0, 0, 0}, -2250}
{{1, 1, 1, 1, 1, 0, 0, 0}, -2250}
{{1, 1, 1, 1, 1, 0, 0, 0}, -2250}
{{1, 1, 0, 1, 1, 0, 0, 0}, -5400}
{{1, 1, 0, 1, 1, 0, 0, 0}, -5400}
{{1, 1, 0, 1, 0, 0, 0, 0}, -5850}
{{1, 1, 0, 1, 0, 1, 0, 0}, -7344}
{{1, 1, 0, 1, 0, 1, 0, 0}, -7344}
{{1, 1, 0, 1, 0, 1, 0, 0}, -7344}
```

```
(*====================   Ap. 6.12. ====================
======================              ====================
======================    RcHeb3P   ====================
Clear[RcHeb3P]
RcHeb3P[v_,A_,p_] :=
        Block[{t,a,b,n},
                Read["ItrHeb3P.m"];
                a = v;
                n = Length[v];
                b=ItrHeb3P[a,A,p];
                t=1;
                While[a!=b,
                  If[t==1,
                     b=ItrHeb3P[a,A,p],
                     a=b;
                     b=ItrHeb3P[a,A,p]];
                     t=t+1];
                Return[b]]*)

(* Ejemplo: *)
Read["p"];Read["RcHeb3P.m"];
RcHeb3P[{1,1,1,1,1,0,0,0},p,0.292893]
Close["p"];Close["RcHeb3P.m"];
Clear[p,RcHeb3P];
{1, 1, 0, 1, 0, 1, 0, 0}
```

```
(*====================   Ap. 6.13. ====================
======================              ====================
======================              ================*)

<<c:\Wnmath22\packages\Graphics\Graphics.m

Read["q"];Read["ProAbs.m"];
Read["VecprPP.m"];
ProAbs[q,4]
F=VecprPP[ProAbs[q,4],q]
Close["q"];Close["ProAbs.m"];Close["VecprPP.m"];
Clear[q,ProAbs,VecprPP]
{1, 1, 0, 1, 0, 1, 0, 0}
 121  89   83   23  21  23  95   107
{---, ---, ---, --, --, --, ---, ---}
 174  174  174  58  58  58  174  174
Show[BarChart[{
        {F[[1]],"1"},
        {F[[2]],"2"},
        {F[[3]],"3"},
        {F[[4]],"4"},
        {F[[5]],"5"},
        {F[[6]],"6"},
        {F[[7]],"7"},
        {F[[8]],"8"}}],
       Graphics[{
       Line[{{-0.8,F[[5]]},{15.3,F[[5]]}}],

       }],
       DisplayFunction:>$DisplayFunction]
```



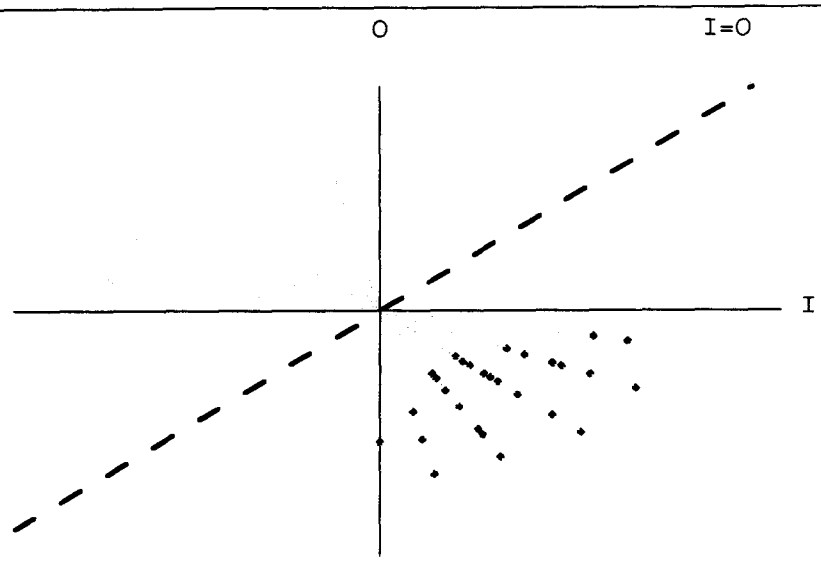
```
(*====================   Ap. 6.14. ====================
======================             ====================
======================             ====================*)
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,0.292893],{i,1,256}];
Close["RcHeb3P.m"];
Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
```




```
-Graphics-
(*====================   Ap. 6.15. ====================
======================             ====================
======================             ====================*)

Read["q"];Read["ProAbs.m"];Read["VecprPP.m"];
F=Table[ProAbs[q,i],{i,1,Length[q]}];
Table[Min[VecprPP[F[[i]],q]],{i,1,Length[q]}]
Close["q"];Close["ProAbs.m"];Close["VecprPP.m"];
Clear[L,q,ProAbs,VecprPP]
   46     5    6    21   8       7       68     1
{(---), --, --, --, --, -(---), -(---), -}
   189    47   35   58   37      215     147    2
```

```
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,-46/189],{i,1,256}];
Close["RcHeb3P.m"];Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
```

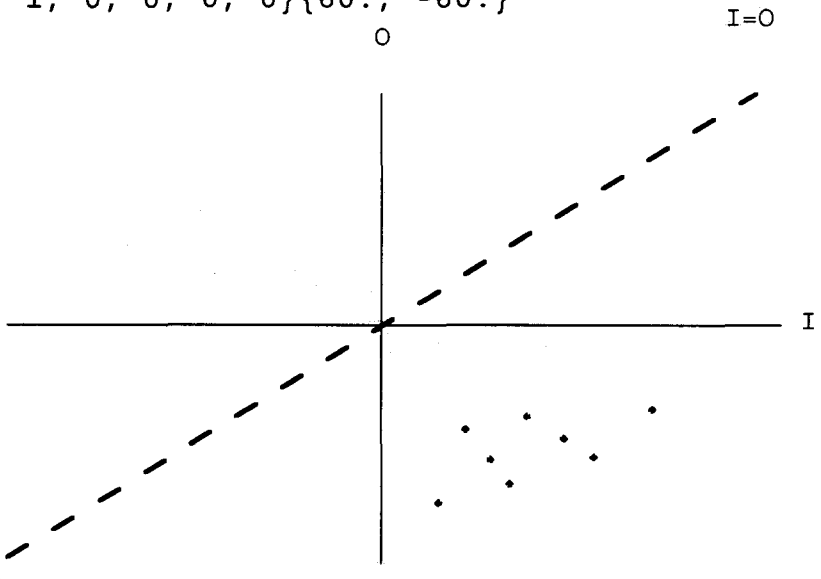
```
{1, 0, 0, 0, 0, 0, 0, 0}{0, -94.5}
{1, 0, 0, 0, 0, 1, 0, 0}{18.5, -92.5}
{1, 0, 0, 0, 1, 0, 0, 0}{14.5, -72.5}
{1, 0, 0, 0, 1, 1, 0, 0}{34.5, -69.}
{1, 0, 0, 1, 0, 0, 0, 0}{18.5, -92.5}
{1, 0, 0, 1, 0, 1, 0, 0}{42.5, -85.}
{1, 0, 0, 1, 0, 1, 1, 0}{36., -36.}
{1, 0, 0, 1, 1, 0, 0, 0}{34.5, -69.}
{1, 0, 0, 1, 1, 1, 0, 0}{60., -60.}
{1, 0, 1, 0, 0, 1, 0, 0}{24.5, -49.}
{1, 0, 1, 0, 1, 1, 0, 0}{33., -33.}
{1, 0, 1, 1, 0, 0, 0, 0}{24.5, -49.}
{1, 0, 1, 1, 0, 1, 0, 0}{45., -45.}
{1, 0, 1, 1, 1, 0, 0, 0}{33., -33.}
{1, 0, 1, 1, 1, 1, 0, 0}{55., -27.5}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
{1, 1, 0, 0, 0, 0, 0, 1}{22.5, -45.}
{1, 1, 0, 0, 0, 0, 1, 0}{28.5, -57.}
{1, 1, 0, 0, 0, 1, 0, 0}{52.5, -105.}
{1, 1, 0, 0, 0, 1, 1, 0}{51., -51.}
{1, 1, 0, 0, 1, 0, 0, 0}{44.5, -89.}
{1, 1, 0, 0, 1, 0, 1, 0}{39., -39.}
{1, 1, 0, 0, 1, 1, 0, 0}{75., -75.}
{1, 1, 0, 0, 1, 1, 1, 0}{63., -31.5}
{1, 1, 0, 1, 0, 0, 0, 0}{52.5, -105.}
{1, 1, 0, 1, 0, 0, 1, 0}{51., -51.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 0, 1, 1, 0}{79., -39.5}
{1, 1, 0, 1, 1, 0, 0, 0}{75., -75.}
{1, 1, 0, 1, 1, 0, 1, 0}{63., -31.5}
{1, 1, 0, 1, 1, 1, 0, 0}{111., -55.5}
{1, 1, 0, 1, 1, 1, 1, 0}{92.5, -18.5}
{1, 1, 1, 0, 0, 0, 0, 0}{34.5, -69.}
{1, 1, 1, 0, 0, 1, 0, 0}{60., -60.}
{1, 1, 1, 0, 1, 0, 0, 0}{48., -48.}
{1, 1, 1, 0, 1, 1, 0, 0}{75., -37.5}
{1, 1, 1, 1, 0, 0, 0, 0}{60., -60.}
{1, 1, 1, 1, 0, 1, 0, 0}{91., -45.5}
{1, 1, 1, 1, 1, 0, 0, 0}{75., -37.5}
{1, 1, 1, 1, 1, 1, 0, 0}{107.5, -21.5}
```



(*Observamos como efectivamente han aparecido como punto fijo el prototipo absoluto a1*)

```
(*************************************************)
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,5/47],{i,1,256}];
Close["RcHeb3P.m"];
Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
```

```
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
{1, 1, 0, 0, 0, 1, 0, 0}{52.5, -105.}
{1, 1, 0, 0, 1, 0, 0, 0}{44.5, -89.}
{1, 1, 0, 0, 1, 1, 0, 0}{75., -75.}
{1, 1, 0, 1, 0, 0, 0, 0}{52.5, -105.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 1, 0, 0, 0}{75., -75.}
{1, 1, 0, 1, 1, 1, 0, 0}{111., -55.5}
{1, 1, 1, 0, 0, 0, 0, 0}{34.5, -69.}
{1, 1, 1, 0, 0, 1, 0, 0}{60., -60.}
{1, 1, 1, 1, 0, 0, 0, 0}{60., -60.}
```

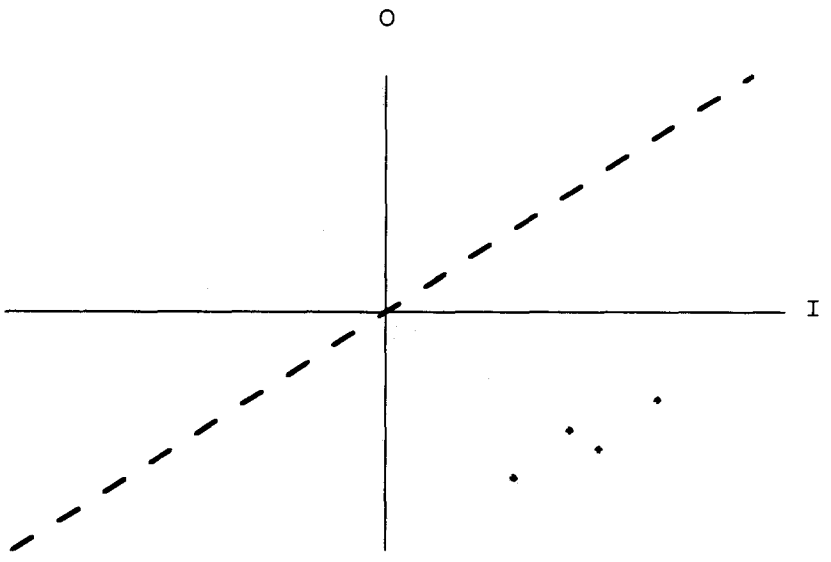


-Graphics-

```
(*Observamos como efectivamente han aparecido como
punto fijo el prototipo absoluto a2*)
```

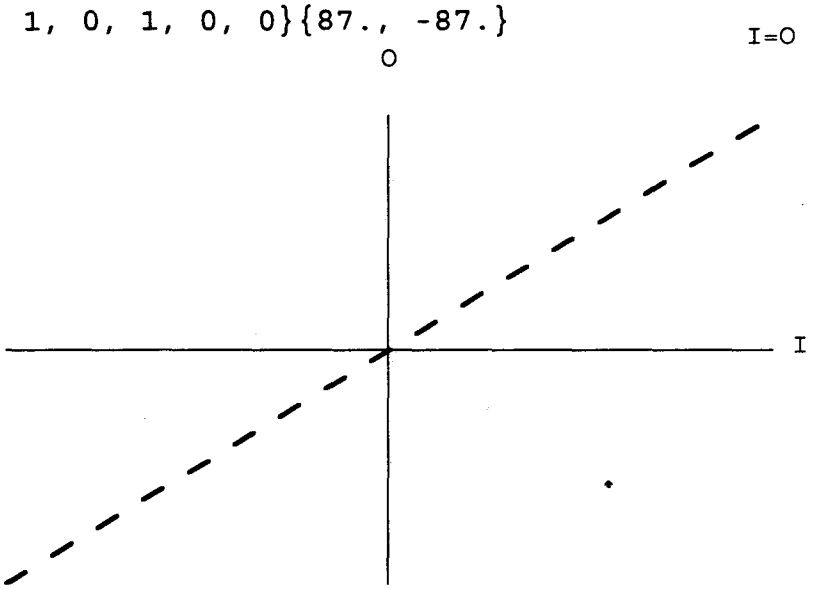
```
(*************************************************)
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,6/35],{i,1,256}];
Close["RcHeb3P.m"];
Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
```

```
{1, 1, 0, 0, 0, 1, 0, 0}{52.5, -105.}
{1, 1, 0, 0, 1, 1, 0, 0}{75., -75.}
{1, 1, 0, 1, 0, 0, 0, 0}{52.5, -105.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 1, 0, 0, 0}{75., -75.}
{1, 1, 0, 1, 1, 1, 0, 0}{111., -55.5}
```



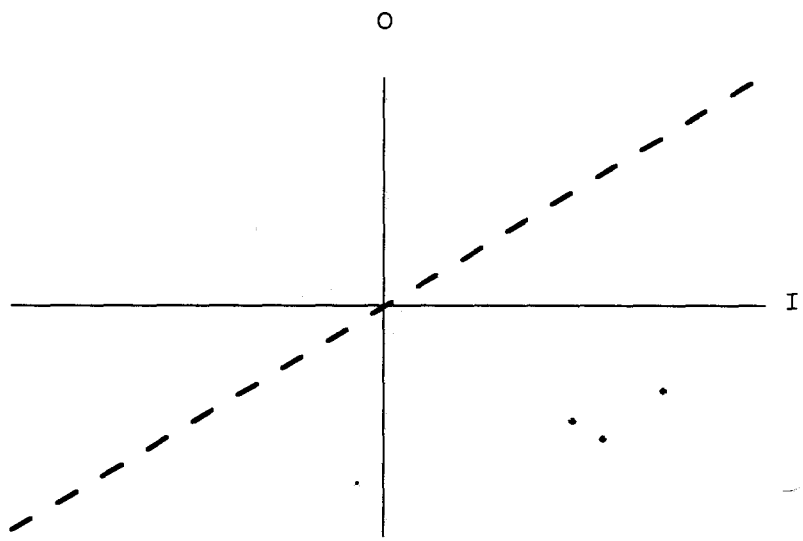

```
(*Observamos como efectivamente han aparecido como
punto fijo el prototipo absoluto a3*)
```

```
(*********************************************)
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,21/58],{i,1,256}];
Close["RcHeb3P.m"];
Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
```




```
(*Observamos como efectivamente han aparecido como
punto fijo el prototipo absoluto a4*)
```

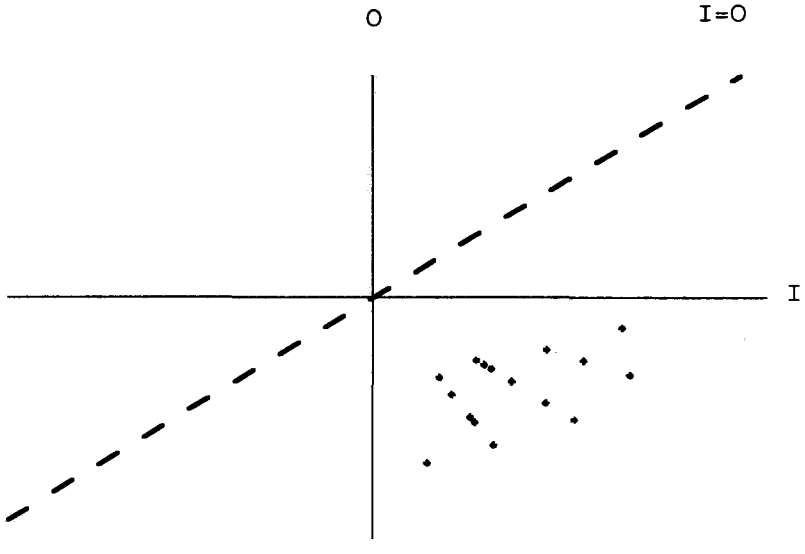
```
(*********************************************)
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,8/37],{i,1,256}];
Close["RcHeb3P.m"];
Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
{1, 1, 0, 0, 1, 1, 0, 0}{75., -75.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 1, 0, 0, 0}{75., -75.}
{1, 1, 0, 1, 1, 1, 0, 0}{111., -55.5}
```




```
(*Observamos como efectivamente han aparecido como
punto fijo el prototipo absoluto a5*)
```

```
(************************************************)
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,-7/215],{i,1,256}];
Close["RcHeb3P.m"];
Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
```

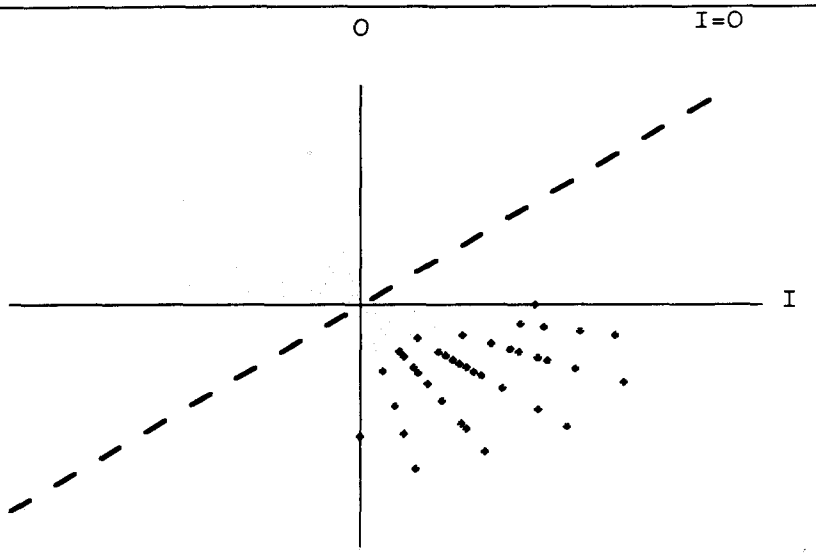
```
{1, 0, 0, 1, 0, 1, 0, 0}{42.5, -85.}
{1, 0, 0, 1, 1, 1, 0, 0}{60., -60.}
{1, 0, 1, 1, 0, 1, 0, 0}{45., -45.}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
{1, 1, 0, 0, 0, 0, 1, 0}{28.5, -57.}
{1, 1, 0, 0, 0, 1, 0, 0}{52.5, -105.}
{1, 1, 0, 0, 0, 1, 1, 0}{51., -51.}
{1, 1, 0, 0, 1, 0, 0, 0}{44.5, -89.}
{1, 1, 0, 0, 1, 1, 0, 0}{75., -75.}
{1, 1, 0, 1, 0, 0, 0, 0}{52.5, -105.}
{1, 1, 0, 1, 0, 0, 1, 0}{51., -51.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 1, 0, 0, 0}{75., -75.}
{1, 1, 0, 1, 1, 1, 0, 0}{111., -55.5}
{1, 1, 1, 0, 0, 0, 0, 0}{34.5, -69.}
{1, 1, 1, 0, 0, 1, 0, 0}{60., -60.}
{1, 1, 1, 0, 1, 0, 0, 0}{48., -48.}
{1, 1, 1, 0, 1, 1, 0, 0}{75., -37.5}
{1, 1, 1, 1, 0, 0, 0, 0}{60., -60.}
{1, 1, 1, 1, 0, 1, 0, 0}{91., -45.5}
{1, 1, 1, 1, 1, 0, 0, 0}{75., -37.5}
{1, 1, 1, 1, 1, 1, 0, 0}{107.5, -21.5}
```




```
(*Observamos como efectivamente han aparecido como
punto fijo el prototipo absoluto a6*)
```

```
Read["q"];Read["Oct.m"];Read["RcHeb3P.m"];
F=Table[RcHeb3P[Oct[[i]],q,-68/147],{i,1,256}];
Close["RcHeb3P.m"];
Clear[RcHeb3P];
Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
```

```
{0, 0, 0, 0, 0, 0, 0, 1}{0, 73.5}
{1, 0, 0, 0, 0, 0, 0, 0}{0, -94.5}
{1, 0, 0, 0, 0, 1, 0, 0}{18.5, -92.5}
{1, 0, 0, 0, 0, 1, 1, 0}{18.5, -37.}
{1, 0, 0, 0, 1, 0, 0, 0}{14.5, -72.5}
{1, 0, 0, 0, 1, 1, 0, 0}{34.5, -69.}
{1, 0, 0, 0, 1, 1, 1, 0}{24., -24.}
{1, 0, 0, 1, 0, 0, 0, 0}{18.5, -92.5}
{1, 0, 0, 1, 0, 0, 1, 0}{18.5, -37.}
{1, 0, 0, 1, 0, 1, 0, 0}{42.5, -85.}
{1, 0, 0, 1, 0, 1, 1, 0}{36., -36.}
{1, 0, 0, 1, 1, 0, 0, 0}{34.5, -69.}
{1, 0, 0, 1, 1, 0, 1, 0}{24., -24.}
{1, 0, 0, 1, 1, 1, 0, 0}{60., -60.}
{1, 0, 0, 1, 1, 1, 1, 0}{43., -21.5}
{1, 0, 1, 0, 0, 0, 0, 0}{9.5, -47.5}
{1, 0, 1, 0, 0, 1, 0, 0}{24.5, -49.}
{1, 0, 1, 0, 1, 0, 0, 0}{16.5, -33.}
{1, 0, 1, 0, 1, 1, 0, 0}{33., -33.}
{1, 0, 1, 1, 0, 0, 0, 0}{24.5, -49.}
{1, 0, 1, 1, 0, 1, 0, 0}{45., -45.}
{1, 0, 1, 1, 1, 0, 0, 0}{33., -33.}
{1, 0, 1, 1, 1, 1, 0, 0}{55., -27.5}
{1, 1, 0, 0, 0, 0, 0, 0}{23.5, -117.5}
{1, 1, 0, 0, 0, 0, 0, 1}{22.5, -45.}
{1, 1, 0, 0, 0, 0, 1, 0}{28.5, -57.}
{1, 1, 0, 0, 0, 1, 0, 0}{52.5, -105.}
{1, 1, 0, 0, 0, 1, 0, 1}{42., -42.}
{1, 1, 0, 0, 0, 1, 1, 0}{51., -51.}
{1, 1, 0, 0, 1, 0, 0, 0}{44.5, -89.}
{1, 1, 0, 0, 1, 0, 1, 0}{39., -39.}
{1, 1, 0, 0, 1, 1, 0, 0}{75., -75.}
{1, 1, 0, 0, 1, 1, 1, 0}{63., -31.5}
{1, 1, 0, 1, 0, 0, 0, 0}{52.5, -105.}
{1, 1, 0, 1, 0, 0, 0, 1}{42., -42.}
{1, 1, 0, 1, 0, 0, 1, 0}{51., -51.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 0, 1, 0, 1}{67., -33.5}
{1, 1, 0, 1, 0, 1, 1, 0}{79., -39.5}
{1, 1, 0, 1, 1, 0, 0, 0}{75., -75.}
{1, 1, 0, 1, 1, 0, 1, 0}{63., -31.5}
{1, 1, 0, 1, 1, 1, 0, 0}{111., -55.5}
{1, 1, 0, 1, 1, 1, 0, 1}{77.5, -15.5}
{1, 1, 0, 1, 1, 1, 1, 0}{92.5, -18.5}
{1, 1, 1, 0, 0, 0, 0, 0}{34.5, -69.}
{1, 1, 1, 0, 0, 0, 1, 0}{24., -24.}
{1, 1, 1, 0, 0, 1, 0, 0}{60., -60.}
{1, 1, 1, 0, 0, 1, 1, 0}{43., -21.5}
{1, 1, 1, 0, 1, 0, 0, 0}{48., -48.}
{1, 1, 1, 0, 1, 1, 0, 0}{75., -37.5}
{1, 1, 1, 1, 0, 0, 0, 0}{60., -60.}
{1, 1, 1, 1, 0, 0, 1, 0}{43., -21.5}
{1, 1, 1, 1, 0, 1, 0, 0}{91., -45.5}
{1, 1, 1, 1, 0, 1, 1, 0}{67.5, -13.5}
{1, 1, 1, 1, 1, 0, 0, 0}{75., -37.5}
{1, 1, 1, 1, 1, 1, 0, 0}{107.5, -21.5}
{1, 1, 1, 1, 1, 1, 1, 0}{73.5, 0}
```



(*Observamos como efectivamente han aparecido como punto fijo el prototipo absoluto a7*)

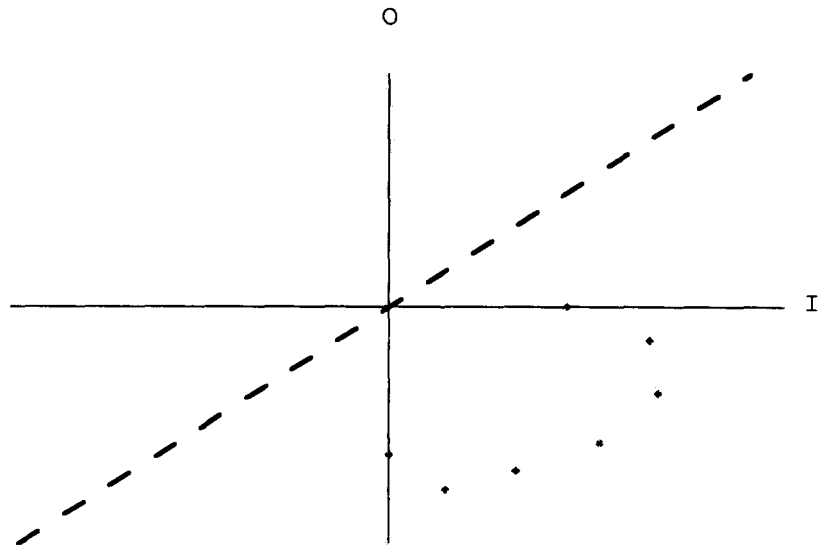
```
(*====================   Ap. 6.16.  ====================
======================                ====================
======================    Heb4P      ==================*)
Clear[Heb4P]
Heb4P[x_,A_,p_,j_Integer]:= Block[{n,Relj,v,a,b,q},
        Read["ReljPP.m"];
        v = x;
        a = x;
        b = x;
        a[[j]] = 1;
        b[[j]] = 0;
        n = Length[x];
        For[i=1,i<=n-1,i++,
         If[x.x==i,q=p[[i]],]];
        Relj = N[ReljPP[x,A,j]];
If[v[[j]]==1,
 If[Relj == q,v = x,
  If[Relj < q,v = b,v = a]],
 If[Relj == q,v = x,
  If[Relj < q,v = a,v = b]]];
        Return[v]]
(* Ejemplo: *)
Read["q"];Read["Heb4P.m"];
Heb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,0,0,0,0},3]
Heb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,-0.1,0,0,0},3]
Heb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,+0.1,0,0,0},3]
Close["q"];Close["Heb4P.m"];
Clear[q,Heb4P];
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
(*====================   Ap. 6.17. ====================
======================              ====================
======================   ItrHeb4P  ====================*)

Clear[ItrHeb4P]
ItrHeb4P[v_,A_,p_] :=
        Block[{a,b,n},
                n = Length[A];
                Read["Heb4P.m"];
                a=v;b=v;
                Do[
                b = Heb4P[a,A,p,i];
                a = b,{i,n}];
                Return[b]]*)
(* Ejemplo: *)
Read["q"];Read["ItrHeb4P.m"];
ItrHeb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,0,0,0,0}]
ItrHeb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,-0.1,0,0,0}]
ItrHeb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,+0.1,0,0,0}]
Close["q"];Close["ItrHeb4P.m"];
Clear[q,ItrHeb4P];
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 0, 0, 0}
```

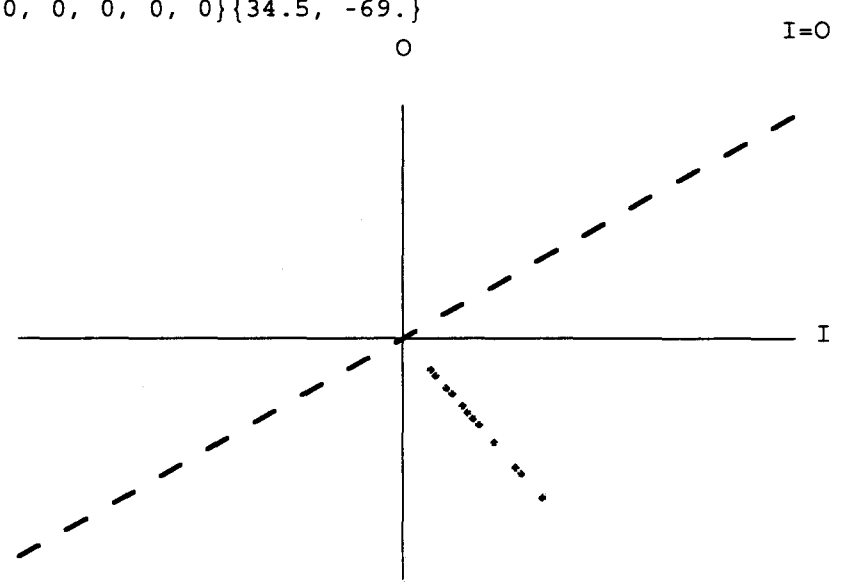
```
(*====================   Ap. 6.18. ====================
======================              ====================
======================   RcHeb4P    ====================*)
Clear[RcHeb4P]
RcHeb4P[v_,A_,p_] :=
        Block[{t,a,b,n},
                Read["ItrHeb4P.m"];
                a = v;
                n = Length[v];
                b=ItrHeb4P[a,A,p];
                t=1;
                While[a!=b,
                  If[t==1,
                     b=ItrHeb4P[a,A,p],
                     a=b;
                     b=ItrHeb4P[a,A,p]];
                     t=t+1];
                Return[b]]*)

(* Ejemplo: *)
Read["q"];Read["RcHeb4P.m"];
RcHeb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,0,0,0,0}]
RcHeb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,-0.1,0,0,0}]
RcHeb4P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,+0.1,0,0,0}]
Close["q"];Close["RcHeb4P.m"];
Clear[q,RcHeb4P];
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 0, 0, 0}

Read["q"];Read["Oct3.m"];Read["RcHeb4P.m"];
RcHeb4P[Oct3[[4]],q,
{-46/189,0,6/35,21/58,8/37,-7/215,-68/147,0}]
Close["q"];Close["Oct3.m"];Close["RcHeb4P.m"];
Clear[q,Oct3,RcHeb4P];
{1, 1, 0, 0, 0, 1, 0, 0}
```

```
(*====================   Ap. 6.19. ====================
======================              ====================
======================              ====================*)

Read["q"];Read["ProAbs.m"];Read["VecprPP.m"];
A = Table[ProAbs[q,i],{i,1,Length[q]}];
B = Table[Min[VecprPP[A[[i]],q]],{i,1,Length[q]}]
Close["q"];Close["ProAbs.m"];Close["VecprPP.m"];
Clear[q,ProAbs,VecprPP,A]

   46    5   6   21  8       7
{{---}, --, --, --, --, -(---),
   189   47  35  58  37      215

   68    1
--(---), -}
   147   2
```

```
(*====================   Ap. 6.20. ====================
======================              ====================
======================              ====================*)
Read["q"];Read["Oct.m"];Read["RcHeb4P.m"];
F = Table[RcHeb4P[Oct[[i]],q,B],{i,1,256}];
Close["RcHeb4P.m"];
Clear[RcHeb4P];

Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F,B];
{1, 0, 0, 0, 0, 0, 0, 0}{0, -94.5}
{1, 1, 0, 0, 0, 0, 0, 0}

 {23.5, -117.5}
{1, 1, 0, 0, 0, 1, 0, 0}

 {52.5, -105.}
{1, 1, 0, 1, 0, 0, 0, 0}

 {52.5, -105.}
{1, 1, 0, 1, 0, 1, 0, 0}{87., -87.}
{1, 1, 0, 1, 1, 1, 0, 0}

 {111., -55.5}
{1, 1, 1, 1, 1, 1, 0, 0}

 {107.5, -21.5}
{1, 1, 1, 1, 1, 1, 1, 0}{73.5, 0}
```



```
(*====================   Ap. 6.21. ====================
======================              ====================
======================              ====================*)
Read["q"];Read["Oct.m"];Read["RcHeb4P.m"];
F = Table[RcHeb4P[Oct[[i]],q,{2,2,-2,2,2,2,2,2}]
,{i,1,256}];
Close["RcHeb4P.m"];
Clear[RcHeb4P];

Read["Pintroj.m"];
Pintroj[F,Oct,q]
Close["q"];Close["Oct.m"];
Close["Pintroj.m"];
Clear[q,Oct,Pintroj,F];
{0, 1, 0, 0, 1, 1, 0, 0}{18.5, -37.}
{0, 1, 0, 1, 0, 1, 0, 0}{26.5, -53.}
{0, 1, 0, 1, 1, 0, 0, 0}{18.5, -37.}
{1, 0, 0, 0, 0, 1, 0, 1}{12.5, -25.}
{1, 0, 0, 0, 0, 1, 1, 0}{18.5, -37.}
{1, 0, 0, 0, 1, 0, 1, 0}{10.5, -21.}
{1, 0, 0, 0, 1, 1, 0, 0}{34.5, -69.}
{1, 0, 0, 1, 0, 0, 0, 1}{12.5, -25.}
{1, 0, 0, 1, 0, 0, 1, 0}{18.5, -37.}
{1, 0, 0, 1, 0, 1, 0, 0}{42.5, -85.}
{1, 0, 0, 1, 1, 0, 0, 0}{34.5, -69.}
{1, 0, 1, 0, 0, 1, 0, 0}{24.5, -49.}
{1, 0, 1, 0, 1, 0, 0, 0}{16.5, -33.}
{1, 0, 1, 1, 0, 0, 0, 0}{24.5, -49.}
{1, 1, 0, 0, 0, 0, 0, 1}{22.5, -45.}
{1, 1, 0, 0, 0, 0, 1, 0}{28.5, -57.}
{1, 1, 0, 0, 0, 1, 0, 0}

 {52.5, -105.}
{1, 1, 0, 0, 1, 0, 0, 0}{44.5, -89.}
{1, 1, 0, 1, 0, 0, 0, 0}

 {52.5, -105.}
{1, 1, 1, 0, 0, 0, 0, 0}{34.5, -69.}
```



```
Clear[Heb5P]
Heb5P[x_,A_,p_,j_Integer]:= Block[{n,Relj,v,a,b,q},
        Read["ReljPP.m"];
        v = x;
        a = x;
        b = x;
        a[[j]] = 1;
        b[[j]] = 0;
        n = Length[x];
        For[i=1,i<=n-1,i++,
         If[x.x==i,q=p[[i]],]];
        Relj = N[ReljPP[x,A,j]];
If[v[[j]]==1,
 If[Relj == q,v = x,
  If[Relj < q,v = b,v = a]],
 If[Relj == q,v = x,
  If[Relj < q,v = a,v = b]]];
Read["Desv.m"];
If[Desv[v,A]<=Desv[x,A],,v=x];
        Return[v]]
Read["q"];
Heb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,0,0,0,0},3]
Heb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,-0.1,0,0,0},3]
Heb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,+0.1,0,0,0},3]
Close["q"];
Clear[q];
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
Clear[ItrHeb5P]
ItrHeb5P[v_,A_,p_] :=
        Block[{a,b,n},
                n = Length[A];
                (*Read["Heb4P.m"];*)
                a=v;b=v;
                Do[
                b = Heb5P[a,A,p,i];
                a = b,{i,n}];
                Return[b]]

Read["q"];
ItrHeb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,0,0,0,0}]
ItrHeb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,-0.1,0,0,0}]
ItrHeb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,+0.1,0,0,0}]
Close["q"];
Clear[q];
```

```
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
Clear[RcHeb5P]
RcHeb5P[v_,A_,p_] :=
        Block[{t,a,b,n},
                (*Read["ItrHeb4P.m"];*)
                a = v;
                n = Length[v];
                b=ItrHeb5P[a,A,p];
                t=1;
                While[a!=b,
                  If[t==1,
                     b=ItrHeb5P[a,A,p],
                     a=b;
                     b=ItrHeb5P[a,A,p]];
                     t=t+1];
                Return[b]]
Read["q"];
RcHeb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,0,0,0,0}]
RcHeb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,-0.1,0,0,0}]
RcHeb5P[{1,1,1,1,1,0,0,0},q,{0,0,0,0,+0.1,0,0,0}]
Close["q"];
Clear[q];
```

```
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 1, 1, 1, 0, 0, 0}
{1, 1, 0, 1, 1, 0, 0, 0}
```

```
Read["q"];Read["ProAbs.m"];Read["VecprPP.m"];
A = Table[ProAbs[q,i],{i,1,Length[q]}];
B = Table[Min[VecprPP[A[[i]],q]],{i,1,Length[q]}]
Close["q"];Close["ProAbs.m"];Close["VecprPP.m"];
Clear[q,ProAbs,VecprPP,A]
```

```
   46    5   6   21  8       7
{(---), --, --, --, --, -(---),
   189   47  35  58  37     215

   68    1
--(---), -}
   147   2
```

```
(*====================   Ap. 6.22. ====================
======================              ====================
=====     CODIFICACIÓN DE LOS DIGITOS ARABIGOS     ====

Nu := {
{0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1},
{1,1,1,1,0,0,0,1,0,0,0,1,1,1,1,1,1,1,0,0,0,1,0,0,0,1,1,1,1},
{1,1,1,1,0,0,0,1,0,0,0,1,1,1,1,1,1,1,0,0,0,1,0,0,0,1,1,1,1},
{1,0,0,1,1,0,0,1,1,0,0,1,1,1,1,1,1,1,0,0,0,1,0,0,0,1,0,0,0,1},
{1,1,1,1,1,0,0,0,1,0,0,0,1,1,1,1,1,1,0,0,0,1,0,0,0,1,1,1,1,1},
{1,0,0,0,1,0,0,0,1,0,0,0,1,1,1,1,1,1,0,0,1,1,0,0,1,1,1,1,1},
{1,1,1,1,0,0,0,1,0,0,0,1,0,0,0,1,1,1,0,0,0,1,0,0,0,1,0,0,0,1},
{1,1,1,1,1,0,0,1,1,0,0,1,1,1,1,1,1,1,0,0,1,1,0,0,1,1,1,1,1},
{1,1,1,1,1,0,0,1,1,0,0,1,1,1,1,1,1,1,0,0,0,1,0,0,0,1,0,0,0,1},
{1,1,1,1,1,0,0,1,1,0,0,1,1,0,0,1,1,0,0,1,1,0,0,1,1,1,1,1,1}}
*)

(* Vemos a que clase pertenece cada digito *)
Read["Nu.m"];
Do[Print[{i,Nu[[i]].Nu[[i]]}],{i,1,10}]
Close["Nu.m"];
{1, 7}
{2, 16}
{3, 16}
{4, 13}
{5, 16}
{6, 15}
{7, 10}
{8, 20}
{9, 15}
{10, 18}
```

```
(*====================   Ap. 6.23. ====================
=====================                ====================
=====     Vector de parámetros que definen la     ====
=====      matriz de pesos, al cual llamamos      ====
=====                      ParNu                  ====

Read["LP2.m"];
ParNu = LP2[Nu]
Save["ParNu.m",ParNu];
Close["LP2.m"];
Clear[LP2,ParNu];

*)

Read["ParNu.m"];
ParNu
Close["ParNu.m"];
 53  25  25  53  11    73     73   39  11    73
{--, --, --, --, --, -(--), -(--), --, --, -(--),
 14  14  14  14  14    14     14   14  14    14

   73   39  39  25  25  67    17     73     73   53
--(--), --, --, --, --, --, -(--), -(--), -(--), --,
   14   14  14  14  14  14    14     14     14   14

   17     73     73   53  11  11  11  67
--(--), -(--), -(--), --, --, --, --, --}
   14     14     14   14  14  14  14  14
```

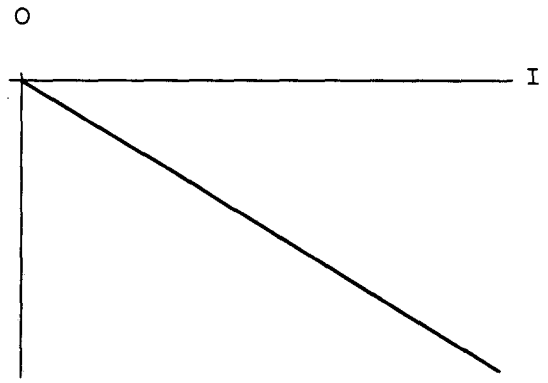
```
(*====================   Ap. 6.24. ====================
======================              ====================
=====         Pares IO de los digitos arábigos      ====
*)

(* Guardamos los pares IO del conjunto Nu

Read["ParNu.m"];Read["ParesPP.m"];
IONu=ParesPP[Nu,ParNu]
Save["IONu.m",IONu];
Close["ParNu.m"];Close["ParesPP.m"];
Clear[ParNu,ParesPP,IONu];
*)

(* Pares IO de los digitos arábigos *)
Read["IONu.m"];
Do[Print[N[IONu[[i]]]],{i,1,10}]
Close["IONu.m"];
Clear[IONu];
{159., -530.}
{488.571, -358.286}
{638.571, -468.286}
{458.571, -535.}
{578.571, -424.286}
{403., -345.429}
{304.714, -575.571}
{792.571, -292.}
{585., -501.429}
{648.429, -343.286}
```

```
(* Guardamos en la tabla G, los coeficientes de las
28 línead de energía

Read["ParNu.m"];Read["r.m"];
G = Table[r[ParNu,j],{j,1,28}];
Save["G.m",G]
Close["ParNu.m"];
Close["r.m"];
Clear[ParNu,r,G]
*)

(* Ejemplo *)

Read["G.m"];
G[[12]]
Close["G.m"];
 1   1
{--, --, 0}
 11  15
```

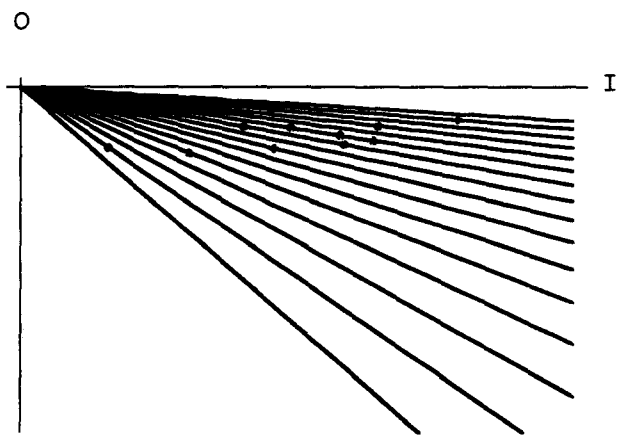
```
(* Pendiented de las 28 rectas
Clear[Pen,i]
Pen[i_Integer] := Block[{a,b,s},
                  Read["G.m"];
                  a = G[[i,1]];
                  b = G[[i,2]];
                  s = -(a/b);
                  Return[s]]


Save["Pen.m",Pen]
*)

(* Ejemplo: pendiente de r4 *)

Read["Pen.m"];
Pen[4]
Close["Pen.m"];
Clear[Pen];
```

$$-\frac{23}{3}$$

```
(* Se dibujan las rectas de energía

Clear[Rec,i]
Rec[i_]:=Block[{},Read["Pen.m"];
        Plot[Pen[i]*x,{x,0,1000},
                PlotStyle->{PointSize[0.001],
                Thickness[0.0001]},
                Ticks->None,
                FrameTicks->None,
                AxesLabel->{"I","O"}]]

Save["Rec.m",Rec]

*)

(* Ejemplo, se dibuja r15  *)

Read["Rec.m"]
Rec[15]
Close["Rec.m"];
Clear[Rec]
```



```
(* Se representas las rectas y los digitos arabigos *)

Read["Rec.m"];
Read["IONu.m"];
Show[Rec[6],Rec[7],Rec[8],Rec[9],Rec[10],
        Rec[11],Rec[12],Rec[13],Rec[14],
        Rec[15],Rec[16],Rec[17],Rec[18],
        Rec[19],Rec[20],Rec[21],
        Graphics[{PointSize[0.01],RGBColor[1,0,0],
        Point[IONu[[1]]],
        Point[IONu[[2]]],
        Point[IONu[[3]]],
        Point[IONu[[4]]],
        Point[IONu[[5]]],
        Point[IONu[[6]]],
        Point[IONu[[7]]],
        Point[IONu[[8]]],
        Point[IONu[[9]]],
        Point[IONu[[10]]]
        }],
        Ticks->None,
        DisplayFunction:>$DisplayFunction]
Close["Rec.m"];
Close["IONu.m"];
Clear[Rec,IONu];
```



```
(*==================   Ap. 6.25. ====================
====================              ====================
==========        Prototipos Absolutos       ==========


Read["ParNu.m"];
Read["VecprPP.m"];
Read["ProAbs.m"];
F=Table[ProAbs[ParNu,i],{i,1,28}]
UmbRec=Table[Min[VecprPP[F[[i]],ParNu]],{i,1,28}];
Save["UmbRec.m",UmbRec];
Close["ParNu.m"];
Close["ProAbs.m"];
Close["VecprPP.m"];
Clear[ParNu,ProAbs,VecprPP,UmbRec,F]
*)
```

```
Read["UmbRec.m"];
Read["ParNu.m"];
Read["ProAbs.m"];
F=Table[ProAbs[ParNu,i],{i,1,28}];
Do[Print[{F[[i]],N[UmbRec[[i]]]}]
,{i,1,28}]
Close["UmbRec.m"];
Close["ParNu.m"];
Close["ProAbs.m"];
Clear[F];
{{0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0,

  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0}, -0.923077}
{{0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0,

  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1}, -0.339701}
{{1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0,

  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1}, -0.229947}
{{1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0,

  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1}, -0.167754}
{{1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1}, -0.127211}
{{1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, -0.0597303}
{{1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, -0.0462338}
{{1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, -0.0345084}
{{1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, 0.00455964}
{{1, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, 0.0106075}
{{1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, 0.0168129}
{{1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, 0.0232962}
{{1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, 0.053286}
{{1, 1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, 0.0592334}
{{1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1}, 0.0660969}
{{1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 1}, 0.0741306}
{{1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1}, 0.0794893}
{{1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0,

  0, 0, 1, 0, 0, 0, 1, 1, 1, 1, 1}, 0.0755759}
{{1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,
```

```
  0, 0, 1, 0, 0, 0, 1, 1, 1, 1, 1}, 0.0288408}
{{1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,

  0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1}, 0.0250541}
{{1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,

  0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1}, -0.0857143}
{{1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,

  0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1}, -0.111111}
{{1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1,

  0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1}, -0.145455}
{{1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,

  0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1}, -0.195652}
{{1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,

  1, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1}, -0.277778}
{{1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,

  1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1}, -0.44}
{{1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,

  1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1}, -0.923077}
{{1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,

  1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}, 0.142857}
```

```
(*==================   Ap. 6.26. ====================
====================              ====================
=  Recuperación digitos arábigos con los umbrales ====
 de capacidad impuestos por los Prototipos absolutos  *)

Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["UmbRec.m"];

Do[Print[{i,Nu[[i]]==RcHeb4P[Nu[[i]],ParNu,UmbRec]}],
{i,1,10}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["UmbRec.m"];
```

```
{1, False}
{2, False}
{3, True}
{4, False}
{5, False}
{6, False}
{7, False}
{8, True}
{9, True}
{10, False}
```

```
(*==================   Ap. 6.27. ====================
======================              ====================
=======  Umbrales de los prototipos de Nu  ===========


Read["ParNu.m"];
Read["VecprPP.m"];
Read["Nu.m"];
UmbNum=Table[Min[VecprPP[Nu[[i]],ParNu]],{i,1,10}]
Save["UmbNum.m",UmbNum];
Close["ParNu.m"];
Close["VecprPP.m"];
Clear[ParNu,VecprPP,UmbNum]
*)

(* Digitos, clase a la que pertenecen y umbral *)
Read["UmbNum.m"];
Read["Nu.m"];
Do[Print[{i,Nu[[i]].Nu[[i]],N[UmbNum[[i]]]}]
,{i,1,10}]
Close["Nu.m"];
Close["UmbNum.m"];

{1, 7, -0.0857143}
{2, 16, -0.0147528}
{3, 16, 0.0741306}
{4, 13, 0.0280374}
{5, 16, 0.0252525}
{6, 15, -0.0372208}
{7, 10, -0.018615}
{8, 20, 0.0250541}
{9, 15, 0.0660969}
{10, 18, 0.028861}
```

```
Read["UmbRec.m"];
Read["ParNu.m"];
Read["ProAbs.m"];
A={7,16,16,13,16,15,10,20,15,18}
F=Table[ProAbs[ParNu,A[[i]]],{i,1,Length[A]}];
Do[Print[{A[[i]],N[UmbRec[[A[[i]]]]]}]
,{i,1,Length[A]}]
Close["UmbRec.m"];
Close["ParNu.m"];
Close["ProAbs.m"];
Clear[F];
```

```
o]
{7, 16, 16, 13, 16, 15, 10, 20, 15, 1
;[o]
{7, -0.0462338}
{16, 0.0741306}
{16, 0.0741306}
{13, 0.053286}
{16, 0.0741306}
{15, 0.0660969}
{10, 0.0106075}
{20, 0.0250541}
{15, 0.0660969}
{18, 0.0755
```

```
(*====================   Ap. 6.28. ====================
======================              ====================
=======  Umbrales de los prototipos de Nu  ===========

Clear[U]
U[m_Integer,n_]:= Block[{a},
                  Read["Cero.m"];
                  a = Cero[28,0];
                  a[[m]]=n;
                  Return[a]]*)


(*
Read["UmbNum.m"];
Read["UmbRec.m"];
Umbral = UmbRec-
(U[7,UmbRec[[7]]]+
U[10,UmbRec[[10]]]+
U[13,UmbRec[[13]]]+
U[15,UmbRec[[15]]]+
U[16,UmbRec[[16]]]+
U[18,UmbRec[[18]]]+
U[20,UmbRec[[20]]])+
(U[7,UmbNum[[1]]]+
U[10,UmbNum[[7]]]+
U[13,UmbNum[[4]]]+
U[15,UmbNum[[6]]]+
U[16,UmbNum[[2]]]+
U[18,UmbNum[[10]]]+
U[20,UmbNum[[8]]]);
Save["Umbral.m",Umbral];

Close["UmbNum.m"];
Close["UmbRec.m"];
Clear[Umbral]
*)
```

```
Read["Umbral.m"];
Do[Print[{i,N[Umbral[[i]]]}]
,{i,1,28}]
Close["Umbral.
```

```
{1, -0.923077}
{2, -0.339701}
{3, -0.229947}
{4, -0.167754}
{5, -0.127211}
{6, -0.0597303}
{7, -0.0857143}
{8, -0.0345084}
{9, 0.00455964}
{10, -0.018615}
{11, 0.0168129}
{12, 0.0232962}
{13, 0.0280374}
{14, 0.0592334}
{15, -0.0372208}
{16, -0.0147528}
{17, 0.0794893}
{18, 0.028861}
{19, 0.0288408}
{20, 0.0250541}
{21, -0.0857143}
{22, -0.111111}
{23, -0.145455}
{24, -0.195652}
{25, -0.277778}
{26, -0.44}
{27, -0.923077}
{28, 0.142857}
```

```
(*====================   Ap. 6.29. ====================
======================              ====================
=======  Recuperación de los elementos de Nu =======*)

Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];

Do[Print[{Nu[[i]]==RcHeb4P[Nu[[i]],ParNu,Umbral]}],
{i,1,10}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
```

```
{True}
{True}
{True}
{True}
{True}
{True}
{True}
{True}
{True}
{True}
```

```
(*====================   Ap. 6.30. ====================
=====================              ====================
=======       Introduce ruido en un patrón       =======*)

Clear[r,ruido]
ruido[r_,i_Integer]:= Block[{s},
                s=r;
                If[r[[i]]==1,s[[i]]=0,s[[i]]=1];
                Return[s]]
```

```
(*====================    Ap. 6.31. ==================*)

Read["Nu.m"];
Read["ruido.m"];
Ru={ruido[Nu[[1]],3],
ruido[Nu[[2]],16],
ruido[Nu[[3]],6],
ruido[Nu[[4]],1],
ruido[Nu[[5]],7],
ruido[Nu[[6]],1],
ruido[Nu[[7]],4],
ruido[Nu[[8]],16],
ruido[Nu[[9]],24],
ruido[Nu[[10]],13]};

Close["Nu.m"];
Close["ruido.m"];

Read["ParNu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];

Do[Print[{Nu[[i]]==RcHeb4P[Ru[[i]],ParNu,Umbral]}],
{i,1,10}]

Close["ParNu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
{False}
{True}
{True}
{True}
{True}
{True}
{True}
{True}
{True}
{True}
```

```
(*====================   Ap. 6.32. ====================
======================              ====================
==      Introduce ruido en un patrón con ruido    ===*)

Read["Nu.m"];
Read["ruido.m"];
RuRu={
ruido[ruido[Nu[[1]],3],4],
ruido[ruido[Nu[[2]],16],2],
ruido[ruido[Nu[[3]],6],10],
ruido[ruido[Nu[[4]],1],2],
ruido[ruido[Nu[[5]],7],4],
ruido[ruido[Nu[[6]],1],2],
ruido[ruido[Nu[[7]],4],6],
ruido[ruido[Nu[[8]],16],7],
ruido[ruido[Nu[[9]],24],23],
ruido[ruido[Nu[[10]],13],11]};

Close["Nu.m"];
Close["ruido.m"];


Read["ParNu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];

Do[Print[{Nu[[i]]==RcHeb4P[RuRu[[i]],ParNu,Umbral]}],
{i,1,10}]

Close["ParNu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
{False}
{True}
{True}
{False}
{True}
{False}
{True}
{True}
{True}
{True}
```

```
(*====================   Ap. 6.33. ====================
======================              ====================
==      Recuperación de los 2550 patrones que están
====     a distancia Hamming uno de los prototipos    ===*)

Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

1-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[1]],i],ParNu,Umbral]==
Nu[[1]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
1 - con - ruido
{1, False}
{2, False}
{3, False}
{4, False}
{5, False}
{6, False}
{7, False}
{8, False}
{9, False}
{10, False}
{11, False}
{12, False}
{13, False}
{14, False}
{15, False}
{16, False}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

2-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[2]],i],ParNu,Umbral]==
Nu[[2]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
2 - con - ruido
{1, False}
{2, False}
{3, False}
{4, False}
{5, False}
{6, False}
{7, False}
{8, False}
{9, False}
{10, False}
{11, False}
{12, False}
{13, False}
{14, False}
{15, False}
{16, True}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

3-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[3]],i],ParNu,Umbral]==
Nu[[3]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
3 - con - ruido
{1, False}
{2, False}
{3, False}
{4, False}
{5, False}
{6, True}
{7, True}
{8, False}
{9, False}
{10, True}
{11, True}
{12, False}
{13, False}
{14, False}
{15, False}
{16, False}
{17, True}
{18, True}
{19, True}
{20, False}
{21, True}
{22, True}
{23, True}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

4-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[4]],i],ParNu,Umbral]==
Nu[[4]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
4 - con - ruido
{1, True}
{2, False}
{3, False}
{4, False}
{5, False}
{6, False}
{7, False}
{8, False}
{9, False}
{10, False}
{11, False}
{12, False}
{13, False}
{14, False}
{15, False}
{16, False}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

5-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[5]],i],ParNu,Umbral]==
Nu[[5]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
5 - con - ruido
{1, False}
{2, False}
{3, False}
{4, False}
{5, False}
{6, True}
{7, True}
{8, False}
{9, False}
{10, False}
{11, False}
{12, False}
{13, False}
{14, False}
{15, False}
{16, True}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, True}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

6-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[6]],i],ParNu,Umbral]==
Nu[[6]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
6 - con - ruido
{1, True}
{2, False}
{3, False}
{4, False}
{5, False}
{6, False}
{7, False}
{8, False}
{9, False}
{10, False}
{11, False}
{12, False}
{13, False}
{14, False}
{15, False}
{16, False}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

7-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[7]],i],ParNu,Umbral]==
Nu[[7]]},{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
7 - con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, False}
{6, True}
{7, True}
{8, True}
{9, False}
{10, True}
{11, True}
{12, True}
{13, False}
{14, False}
{15, False}
{16, False}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

8-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[8]],i],ParNu,Umbral]==
Nu[[8]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
8 - con - ruido
{1, False}
{2, False}
{3, False}
{4, False}
{5, False}
{6, False}
{7, False}
{8, False}
{9, False}
{10, False}
{11, False}
{12, False}
{13, False}
{14, False}
{15, False}
{16, True}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

9-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[9]],i],ParNu,Umbral]==
Nu[[9]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

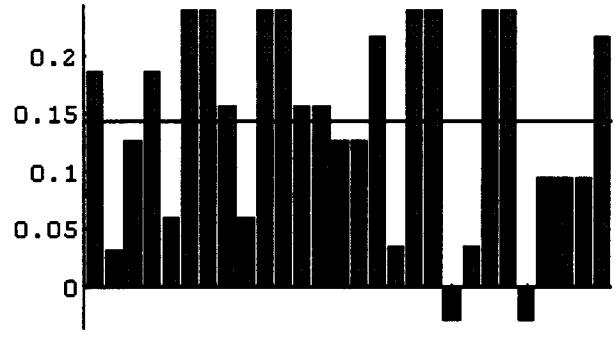
```
9 - con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, False}
{6, True}
{7, True}
{8, True}
{9, False}
{10, True}
{11, True}
{12, True}
{13, True}
{14, True}
{15, True}
{16, True}
{17, False}
{18, True}
{19, True}
{20, True}
{21, False}
{22, True}
{23, True}
{24, True}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
Read["ParNu.m"];Read["Nu.m"];
Read["RcHeb4P.m"];
Read["Umbral.m"];
Read["ruido.m"];

0-con-ruido

Do[Print[{i,RcHeb4P[ruido[Nu[[10]],i],ParNu,Umbral]==
Nu[[10]]}],{i,1,28}]

Close["ParNu.m"];Close["Nu.m"];
Close["RcHeb4P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
-con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, False}
{6, True}
{7, True}
{8, True}
{9, False}
{10, True}
{11, True}
{12, True}
{13, True}
{14, False}
{15, False}
{16, False}
{17, False}
{18, False}
{19, False}
{20, False}
{21, False}
{22, False}
{23, False}
{24, False}
{25, False}
{26, False}
{27, False}
{28, False}
```

```
(*====================   Ap. 6.34. ====================
======================              ====================
======================              ==================*)

Read["LP2.m"];Read["Nu.m"];
p=LP2[Nu];Read["VecprPP.m"];
Read["ruido.m"];
r=ruido[Nu[[2]],2]
G=N[VecprPP[r,p]]
Min[G]
Close["VecprPP.m"];
Clear[p,VecprPP,r];
{1, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1,

 1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1,

 1, 1}
{0.185615, 0.0301624, 0.12529,

 0.185615, 0.0599381, 0.238592,

 0.238592, 0.155452, 0.0599381,

 0.238592, 0.238592, 0.155452,

 0.155452, 0.12529, 0.12529, 0.215777,

 0.0348028, 0.238592, 0.238592,

 -0.029389, 0.0348028, 0.238592,

 0.238592, -0.029389, 0.0951276,

 0.0951276, 0.0951276, 0.215777}
-0.029389
<<c:\Wnmath22\packages\Graphics\Graphics.m

m=4/28
1
-
7
```

```
Show[BarChart[{
          {G[[1]],"    "},
          {G[[2]],"    "},
          {G[[3]],"    "},
          {G[[4]],"    "},
          {G[[5]],"    "},
          {G[[6]],"    "},
          {G[[7]],"    "},
          {G[[8]],"    "},
          {G[[9]],"    "},
          {G[[10]],"    "},
          {G[[11]],"    "},
          {G[[12]],"    "},
          {G[[13]],"    "},
          {G[[14]],"    "},
          {G[[15]],"    "},
          {G[[16]],"    "},
          {G[[17]],"    "},
          {G[[18]],"    "},
          {G[[19]],"    "},
          {G[[20]],"    "},
          {G[[21]],"    "},
          {G[[22]],"    "},
          {G[[23]],"    "},
          {G[[24]],"    "},
          {G[[25]],"    "},
          {G[[26]],"    "},
          {G[[27]],"    "},
          {G[[28]],"    "}}],
          Graphics[{
          Line[{{-0.8,m},{45.3,m}}],
                }],
          DisplayFunction:>$DisplayFunction]
```




```
(*====================   Ap. 6.35. ====================
=====================              ====================
=====================              ==================*)

Clear[Desv]
Desv[v_,A_] :=
        Block[{a,b,d,e,n,j,i,s},
                n = Length[A];
                Read["Prelpar.m"];
                Read["Cero.m"];
                d = Cero[n,0];
                e = Cero[n,0];
                a = 0;
                b = 0;
                m = 4/n;
                For[j=1,j<=n,j++,
                a = Prelpar[v,A,j];
                d[[j]] = a];
                For[i=1,i<=n,i++,
                b = (d[[i]] - m)^2;
                e[[i]] = b];
                s = N[(Sum[e[[i]],{i,1,n}])^(1/2)];
                Return[s]]
*)
```

```
(*====================    Ap. 6.36. ====================
=====================              ====================
=====================              ==================*)

Read["ParNu.m"];
Read["Nu.m"];
Read["Desv.m"];
ParDes=Table[Desv[Nu[[i]],ParNu],{i,1,10}];
Save["ParDes.m",ParDes]
Close["ParNu.m"];
Close["Nu.m"];
Close["Desv.m"];
*)

Read["ParDes.m"];
ParDes
Close["ParDes.m"];
{0.6953634846033885,

 0.4195247749269397, 0.239724925093533,

 0.3048889233349272,

 0.3064016195141191,

 0.5015157930394762,

 0.4386586529379624,

 0.3982336995525956, 0.239022825343198,

 0.3587273623278634}
```

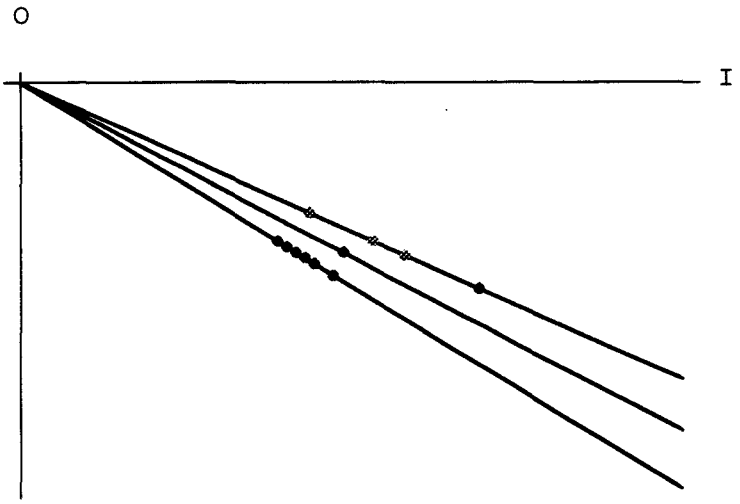
```
(*====================   Ap. 6.37. ====================
=====================              ====================
=====================              ==================*)

Clear[RcHeb5P]
RcHeb5P[v_,A_,p_,q_] :=
        Block[{a,b,n,t,l,h,c,d,s,e,f},
                t = Length[q];
                n = Length[v];
                s = {};
                Read["Desv.m"];


(* Primero vemos si el vector de entrada tiene alguna
desviación del vector de desviaciones,si es asi se le
da salida en s y se activa el switch h *)

                h = 0;
                c = Desv[v,A];
                For [i=1,i<=t,++i,
                 If[c == q[[i]],s=v;h=1, ]];


(* Si el switch h está activado no se hace nada, en
caso contrario si algún vector del entorno de radio 1
del vector de entrada tiene alguna desviación del vector
de desviaciones,si es asi se le da salida en s y
se activa el switch l *)

        l = 0;
        If[h != 0,,
                 For[j=1,j<=n,++j,
                  b = ruido[v,j];
                  c = Desv[b,A];
                  For [i=1,i<=t,++i,
                   If[c==q[[i]],s=b;j=n;i=t;l=1,]]]];


(* si en ninguno de los dos casos anteriores no obtuvimos
salida se recupera el vector de entrada en a, y se
mira si tiene alguna desviación del vector
de desviaciones dandole salida en s y activando f *)


        If[(h != 0 Or l != 0),,
                t = Length[q];
                n = Length[v];
                f = 0;
                Read["RcHeb4P.m"];
                a = RcHeb4P[v,A,p];
                d = Desv[a,t,A];
                 For [i=1,i<=t,++i,
                  If[d==q[[i]],s=a;f=1, ]]];
```

```
(* Si no hay ningun switch activado se buscan en los
vecinos de a si tiene alguna desviación del vector
de desviaciones dandole salida en s si es asi*)


        If[(h+l+f != 0),,

                For[j=1,j<=n,++j,
                 b = ruido[a,j];
                 d = Desv[b,A];
                 For [i=1,i<=t,++i,
                 If[d==q[[i]],s=b;j=n;i=t,s=a]]];

               Return[s]]

Save["RcHeb5P.m",RcHeb5P]
```

```
Read["Nu.m"];
Read["ruido.m"];

s1={
ruido[Nu[[2]],1],
ruido[Nu[[2]],2],
ruido[Nu[[2]],3],
ruido[Nu[[2]],4],
ruido[Nu[[2]],8],
ruido[Nu[[2]],12],
ruido[Nu[[2]],13],
ruido[Nu[[2]],14],
ruido[Nu[[2]],15],
ruido[Nu[[2]],16],
ruido[Nu[[2]],17],
ruido[Nu[[2]],21],
ruido[Nu[[2]],25],
ruido[Nu[[2]],26],
ruido[Nu[[2]],27],
ruido[Nu[[2]],28]};

Save["s1.m",s1];
Close["Nu.m"];
Close["ruido.m"];
```

```
Read["Nu.m"];
Read["ruido.m"];

s2={
ruido[Nu[[2]],5],
ruido[Nu[[2]],6],
ruido[Nu[[2]],7],
ruido[Nu[[2]],9],
ruido[Nu[[2]],10],
ruido[Nu[[2]],11],
ruido[Nu[[2]],18],
ruido[Nu[[2]],19],
ruido[Nu[[2]],20],
ruido[Nu[[2]],22],
ruido[Nu[[2]],23],
ruido[Nu[[2]],24]};
Save["s2.m",s2];

Close["Nu.m"];
Close["ruido.m"];
Read["ParNu.m"];
Read["ParesPP.m"];
Read["s1.m"];
IOs1=ParesPP[s1,ParNu];
Save["IOs1.m",IOs1];
Close["ParNu.m"];Close["ParesPP.m"];Close["s1.m"];
Clear[ParNu,ParesPP,IOs1];
Read["ParNu.m"];Read["ParesPP.m"];
Read["s2.m"];
IOs2=ParesPP[s2,ParNu];
Save["IOs2.m",IOs2];
Close["ParNu.m"];Close["ParesPP.m"];Close["s2.m"];
Clear[ParNu,ParesPP,IOs2];
```

```
(* Se representas las rectas y los digitos arabigos *)

Read["Rec.m"];
Read["Nu.m"];
Read["IOs1.m"];
Read["IOs2.m"];
Read["IONu.m"];
Read["IOPA.m"];


Show[
        Rec[15],Rec[16],Rec[17],
        Graphics[{PointSize[0.01],
        Point[IONu[[6]]],
        Point[IOPA[[17]]],
        RGBColor[0,0,1],
        Point[IOs1[[1]]],
        Point[IOs1[[2]]],
        Point[IOs1[[3]]],
        Point[IOs1[[4]]],
        Point[IOs1[[5]]],
        Point[IOs1[[6]]],
        Point[IOs1[[7]]],
        Point[IOs1[[8]]],
        Point[IOs1[[9]]],
        Point[IOs1[[10]]],
        Point[IOs1[[11]]],
        Point[IOs1[[12]]],
        Point[IOs1[[13]]],
        Point[IOs1[[14]]],
        Point[IOs1[[15]]],
        Point[IOs1[[16]]],
        PointSize[0.01],RGBColor[1,0,0],
        Point[IONu[[2]]],
        PointSize[0.01],RGBColor[0,1,0],
        Point[IOs2[[1]]],
        Point[IOs2[[2]]],
        Point[IOs2[[3]]],
        Point[IOs2[[4]]],
        Point[IOs2[[5]]],
        Point[IOs2[[6]]],
        Point[IOs2[[7]]],
        Point[IOs2[[8]]],
        Point[IOs2[[9]]],
        Point[IOs2[[10]]],
        Point[IOs2[[11]]],
        Point[IOs2[[12]]],
        PointSize[0.01]
        }],
        Ticks->None,
        DisplayFunction:>$DisplayFunction]
Close["Rec.m"];
Close["IOs1.m"];
Close["IOs2.m"];
Close["IONu.m"];
Close["IOPA.m"];
```


O
I

```
(*====================    Ap. 6.38. ====================
=====================              ====================
=====================              ==================*)

Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

1-con-ruido


Do[Print[{i,
Nu[[1]]==RcHeb5P[ruido[Nu[[1]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
1 - con - ruido
{1, True}
{2, True}
{3, True}
{4, False}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, False}
{14, True}
{15, True}
{16, True}
{17, True}
{18, True}
{19, True}
{20, False}
{21, True}
{22, True}
{23, True}
{24, False}
{25, True}
{26, True}
{27, True}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

2-con-ruido


Do[Print[{i,
Nu[[2]]==RcHeb5P[ruido[Nu[[2]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
2 - con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, True}
{14, True}
{15, True}
{16, True}
{17, True}
{18, True}
{19, True}
{20, False}
{21, True}
{22, True}
{23, True}
{24, False}
{25, False}
{26, False}
{27, False}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];
Read["Desv.m"];
Read["ParPP.m"];
2-con-ruido


r=RcHeb5P[ruido[Nu[[2]],20],ParNu,Umbral,ParDes]
Desv[Nu[[2]],ParNu]
Desv[r,ParNu]
ParPP[Nu[[2]],ParNu]
ParPP[r,ParNu]

Close["ParNu.m"];
Close["Desv.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
2 - con - ruido
{0, 1, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1,

 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 0,

 1, 1, 1, 1}
0.419525
0.419525
 3420    2508
{----, -(----)}
  7       7
 3420    2508
{----, -(----)}
  7       7
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

3-con-ruido


Do[Print[{i,
Nu[[3]]==RcHeb5P[ruido[Nu[[3]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
3 - con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, True}
{14, True}
{15, True}
{16, True}
{17, True}
{18, True}
{19, True}
{20, True}
{21, True}
{22, True}
{23, True}
{24, True}
{25, False}
{26, False}
{27, False}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

4-con-ruido


Do[Print[{i,
Nu[[4]]==RcHeb5P[ruido[Nu[[4]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
4 - con - ruido
{1, True}
{2, True}
{3, False}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, True}
{14, False}
{15, False}
{16, True}
{17, True}
{18, True}
{19, True}
{20, True}
{21, True}
{22, True}
{23, True}
{24, True}
{25, False}
{26, False}
{27, False}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

5-con-ruido


Do[Print[{i,
Nu[[5]]==RcHeb5P[ruido[Nu[[5]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
5 - con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, False}
{14, True}
{15, True}
{16, True}
{17, True}
{18, True}
{19, True}
{20, True}
{21, True}
{22, True}
{23, True}
{24, True}
{25, True}
{26, True}
{27, True}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

6-con-ruido


Do[Print[{i,
Nu[[6]]==RcHeb5P[ruido[Nu[[6]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
6 - con - ruido
{1, True}
{2, True}
{3, True}
{4, False}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, False}
{14, False}
{15, False}
{16, True}
{17, True}
{18, True}
{19, True}
{20, False}
{21, True}
{22, True}
{23, True}
{24, False}
{25, True}
{26, True}
{27, True}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

7-con-ruido


Do[Print[{i,
Nu[[7]]==RcHeb5P[ruido[Nu[[7]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
Clear[r];
```

```
7 - con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, False}
{14, False}
{15, False}
{16, True}
{17, True}
{18, True}
{19, True}
{20, True}
{21, True}
{22, True}
{23, True}
{24, True}
{25, True}
{26, True}
{27, True}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

8-con-ruido


Do[Print[{i,
Nu[[8]]==RcHeb5P[ruido[Nu[[8]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
```

```
8 - con - ruido
{1, True}
{2, True}
{3, False}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, True}
{14, False}
{15, False}
{16, True}
{17, True}
{18, True}
{19, True}
{20, True}
{21, True}
{22, True}
{23, True}
{24, True}
{25, True}
{26, True}
{27, True}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

9-con-ruido


Do[Print[{i,
Nu[[9]]==RcHeb5P[ruido[Nu[[9]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
```

```
9 - con - ruido
{1, True}
{2, True}
{3, False}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, True}
{14, False}
{15, False}
{16, True}
{17, True}
{18, True}
{19, True}
{20, True}
{21, True}
{22, True}
{23, True}
{24, True}
{25, False}
{26, False}
{27, False}
{28, True}
```

```
Read["ParNu.m"];
Read["Nu.m"];
Read["RcHeb5P.m"];
Read["Umbral.m"];
Read["ruido.m"];
Read["ParDes.m"];

0-con-ruido


Do[Print[{i,
Nu[[10]]==RcHeb5P[ruido[Nu[[10]],i],ParNu,Umbral,ParDes]}],
{i,1,28}]


Close["ParNu.m"];
Close["Nu.m"];
Close["RcHeb5P.m"];
Close["Umbral.m"];
Close["ruido.m"];
-con - ruido
{1, True}
{2, True}
{3, True}
{4, True}
{5, True}
{6, True}
{7, True}
{8, True}
{9, True}
{10, True}
{11, True}
{12, True}
{13, True}
{14, False}
{15, False}
{16, False}
{17, True}
{18, True}
{19, True}
{20, True}
{21, True}
{22, True}
{23, True}
{24, True}
{25, False}
{26, False}
{27, False}
{28, False}
```